This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

LANE MEDICAL LIBRARY STANFORD
2 45 0061 7161

Digestion and Diet

R William Roberts, M.D., F.R.S.

LANE

SEAL OF THE LELAND STANFORD JUNIOR UNIVERSITY
SEMPER VIRENS
1885

CAL LIBRARY

Gift of

Dr. J. J. Tully.

which is poured into the blood. Accordingly we observe that retarding agents (tea, coffee, and alcoholic beverages) are not used at all, or only used sparingly, by infants and children.

If this view of digestive retardation in the stomach be well founded, the stomach becomes in some degree a storage organ for food—like the crop of birds, the paunch of ruminants, the dilatable cheeks of monkeys, and the pouch of the pelican.

Use of Salt.—Why do we use so much salt with our food? Animals in a state of nature require none. They find (with most rare exceptions) all the salt they require in their natural food; but cooks are always adding salt in their culinary operations, and we have it nearly always on our plates. This habit is probably dependent on the elaborate preparation and cooking to which we subject our food. In the preparation of flour the wheat is robbed of its outer coating, or bran, which contains the larger part of the saline matters of the grain. Potatoes and green vegetables are boiled in large quantities of water, and are therefore deprived of their saline ingredients. Meat and fish are boiled or roasted, and thereby lose some of their mineral constituents. Salt must therefore be supplied artificially to make up the defect, and to restore to the food so treated that sapidity and salinity of which it has in part been deprived. It has been remarked that tribes and races which subsist chiefly on a vegetable diet have more need of salt than meat-
communities.

EFFECT OF FOOD-ACCESSORIES ON

The effects of the food
digestion must obviously be

difficult to estimate, than in the case of salivary and peptic digestion. These accessories undergo changes in the stomach; alcohol and saline matters are largely absorbed in that viscus, so that the beverages containing them are considerably modified by the time they reach the duodenum. And not only are the accessories altered by their sojourn in the stomach, but the articles of food are also profoundly altered. Digestion is already half accomplished, the solid proteids are partly reduced to a state of solution, and the entire gastric mass is converted into a more or less homogeneous chyme. When this enters the duodenum it encounters the alkaline secretions of the liver and pancreas. A large part of the dissolved matter is reprecipitated by the neutralisation which then occurs, and the whole digesting mixture becomes alkaline in reaction. The digestion of starchy matters, suspended in the stomach, is now actively resumed; the digestion of the undissolved proteid matters which came through the pylorus, and of the neutralisation precipitate, recommences and proceeds to its final termination.

Pancreatic digestion appeared in my experiments, except [illegible] of milk and farinaceous matters, to be [illegible] han gastric digestion. On meat-an [illegible] albumen pancreatic extract [illegible] but on milk the action was [illegible] n bread. The agency of [illegible] ecessary for the digestion [illegible]

[illegible] f food-accessories on pan- [illegible] o distinguish between the [illegible] of pancreatic juice.

[illegible] *on Pancreatic Diastase.*—The [illegible] pancreatic digestion of starch [illegible] al with its effect on salivary

DR. J. J. TULLY
STOCKTON, CALIF.

DIGESTION AND DIET

COLLECTED CONTRIBUTIONS
ON
DIGESTION AND DIET

WITH AN APPENDIX
ON
THE OPIUM HABIT IN INDIA

BY

SIR WILLIAM ROBERTS, M.D., F.R.S.
FORMERLY PHYSICIAN TO THE MANCHESTER ROYAL INFIRMARY
AND PROFESSOR OF MEDICINE IN THE VICTORIA UNIVERSITY

SECOND EDITION

LONDON
SMITH, ELDER, & CO., 15 WATERLOO PLACE
1897

[All rights reserved]

U210
R64
1897

PREFACE

THE present volume consists mainly of a reprint of two publications by the author—namely, the Lumleian Lectures 'On the Digestive Ferments and Artificially Digested Food,' delivered before the College of Physicians in 1880, and a course of five Lectures 'On Dietetics and Dyspepsia,' given at the Owens College in 1885. These two little books, after running through two editions, were still called for; and it appeared more advisable to reissue them in conjunction than to print new editions of them separately. The opportunity seemed also a favourable one for bringing together into a collected form, convenient for reference, the other contributions of the author on kindred subjects. These include: a paper 'On the Therapeutics of Starch Digestion,' published in *The Practitioner* for 1879; a paper 'On the Estimation of the Amylolytic and Proteolytic Activity of Pancreatic Extracts,' printed in the *Proceedings of the Royal Society* for 1881; an address 'On Feeding the Sick,' delivered at the meeting of the British Medical Association at Cardiff in 1885; some observations 'On the Use of Gastric Antacids,' made before the Section of Therapeutics at a meeting of the same Society in Leeds in

90277

1889, and, lastly, an address 'On some Practical Points in Dietetics,' delivered before the Manchester Medical Society in October 1890.

The volume therefore embraces all the contributions which the author has made to subjects relating to Digestion, Dietetics, and Dyspepsia.

The matters treated of have been thrown together into four groups or sections; and the materials have been subjected to some amount of rearrangement. By this means a certain degree of order and coherence has been given to the entire work; but no attempt has been made to produce a systematic treatise. The articles have all been carefully revised; and repetitions have been eliminated as far as was practicable; but no substantial changes have been made in the subject-matter.

The present edition is enlarged by the addition, in the form of an appendix, of an article on the Opium Habit in India. This article first appeared as an 'annexure' to the Report of the Royal Commission on Opium, published in 1895. It is here reproduced as a contribution to our knowledge of a group of *quasi*-dietetic substances, which includes alcohol, tobacco, tea and coffee, concerning the true significance of which we are still greatly in need of enlightenment.

W. R.

LONDON: *February* 1897.

CONTENTS

SECTION I.

DIGESTION AND THE DIGESTIVE FERMENTS.

I.—DIGESTION IN GENERAL—THE DIGESTIVE FERMENTS —DIGESTION OF THE CARBOHYDRATES.

PAGE
Digestion is a faculty or function common to animals and plants . 3
Exterior digestion 4
Interstitial digestion 6
General character and properties of the digestive ferments . . 9
    Peculiarity of the albuminous matter contained in solutions of the proteolytic ferments 13
    On nomenclature 15
Preparation of artificial digestive juices 16
    Boracic solution 17
    Dilute spirit 17
    Chloroform-water 18
Diastasic ferments and the digestion of starch 19
    Theory of starch transformation 21
The respective shares of saliva and pancreatic juice in the digestion of starch 27
When can starch be said to be fully digested ? 29
Absolute energy of diastase 31
Digestion of cane-sugar—the inversive ferment 36

II.—DIGESTION OF PROTEIDS—THE MILK-CURDLING FERMENT—THE EMULSIVE FERMENT.

PAGE
Pepsin and trypsin—digestion of proteids 39
Nature of the acid of gastric juice 40
The effect of gastric juice on the salivary and pancreatic ferments 43
Digestive proteolysis 47
Characters of peptones 48
Comparison of the action of pepsin and trypsin 51
Peptogens 54
The milk-curdling ferment 56
    Curdling ferment of the pancreas 56
    What is the function of the milk-curdling ferment? . . . 58
Emulsive ferment—the digestion of fats 59
    Opinions and observations of Bernard 60
    Author's observations 61
    Brücke's and Gad's observations 62

III.—THE ESTIMATION OF THE ACTIVITY OF PANCREATIC EXTRACTS.

Preliminary observations 66
Diastasimetry 68
    Standard starch mucilage 69
    Effect of quantity and time 70
    Effect of temperature 73
    Mode of proceeding 74
    Mode of calculating and expressing the diastasic value . . 76
    Diastasic value of the pancreas of the pig, ox, and sheep . . 78
    Diastasic value of saliva and malt 79
Trypsimetry 80
    Metacasein reaction 80
    Effect of quantity and time 83
    Effect of temperature 84
    Mode of proceeding 87
    Mode of calculating and expressing the tryptic value . . 88
    Comparison of the enzymic values of the pancreas of the pig, ox, and sheep 89

SECTION II.

DIETETICS.

I.—INTRODUCTORY—ON DIETETICS IN GENERAL.

PAGE
Dyspeptic troubles more common in man than in animals . . 93
Causes of this—complexities of the human dietary 94
Basis of scientific dietetics—dietetic customs 96
On the use of meat 98
On the use of alcoholic beverages 99
On the use of tea, coffee, and cocoa 101
Dietetic habits of the two sexes 103
Dietetic habits of infants and children—and of the aged . . . 104
Personal and family idiosyncrasies 105
Effect of the quality of the food on nutrition and vital habits . . 106
High feeding and low feeding 108
Comparison of bodily and mental qualities of high-fed and low-fed classes and races 109

II.—EFFECT OF FOOD-ACCESSORIES ON SALIVARY DIGESTION.

Preliminary remarks 112
Method of experimentation 114
Effect of alcoholic beverages 115
  Proof spirit, brandy, whisky, and gin 115
  Wines 117
  Acids 118
  Malt liquors 119
  Effervescent table waters 119
  Effects of tea, coffee, and cocoa, &c. 120
    Tea—tannin 121
    Coffee and cocoa 124
    Beef-tea, salt, and sugar 125

III.—EFFECT OF FOOD-ACCESSORIES ON PEPTIC DIGESTION.

Method of experimentation 127
Varying quantities of hydrochloric acid 130
Varying quantities of pepsin 131

PAGE
Effect of alcoholic beverages . . . 132
Proof spirit, brandy, whisky, gin . . . 132
Sherry and port wine . . . 133
Claret, hock, and champagne . . . 135
Malt liquors . . . 136
Effervescent table waters . . . 137
Effects of tea and coffee . . . 138
Beef-tea and whey . . . 140

IV.—EFFECT OF FOOD-ACCESSORIES ON PEPTIC DIGESTION, CONTINUED—THEIR EFFECT ON PANCREATIC DIGESTION.

Causes of the retarding effects of food-accessories on peptic digestion . . . 143
In the cases of beef-tea and whey . . . 144
Retarding effects of salts of the organic acids . . . 146
Retarding effects of inorganic neutral salts . . . 146
Effects of superacidulation . . . 147
Effects of dialysis . . . 149
The alkaloids and volatile oils of tea and coffee . . . 150
Has retardation of gastric digestion a beneficial purpose? . . . 153
Use of salt . . . 156
EFFECTS OF FOOD-ACCESSORIES ON PANCREATIC DIGESTION . . . 156
Effects of food-accessories on pancreatic diastase . . . 157
Effects of food-accessories on tryptic digestion . . . 158

V.—ON SOME PRACTICAL POINTS IN DIETETICS.

Preliminary remarks . . . 160
Proper basis for the study of dietetics . . . 162
Man strictly subject to biological laws . . . 163
Double aim of diet . . . 163
What is a luxury? . . . 164
Diversity of our diet . . . 164
Useless restrictions on the choice of food . . . 165
Office of the palate in the choice of food . . . 166
Beneficial effect of change of diet . . . 168
Better to lessen than to forbid . . . 169
The neurotic or hysterical stomach . . . 170
Mid-life revision of diet . . . 171
How to restrict the intake of food . . . 173
Concluding remarks . . . 173

SECTION III.

PREPARATION OF FOOD FOR INVALIDS.

I.—PREPARATION OF ORDINARY FOODS FOR INVALIDS.

PAGE
Effects and purposes of cooking 177
Clinical relations of gastric and intestinal digestion 180
Feeding the sick with liquid food 182
Milk 183
Beef-tea and other meat decoctions 184
Cold-made infusions of meat 185
Beaten-up eggs 186
Fortified gruels 187
Different kinds of farinaceous flours 188
Commercial 'foods' for invalids 188
Apparatus and ingredients required for the preparation of foods in the sick room and nursery 190

II.—PREPARATION AND USE OF ARTIFICIALLY DIGESTED FOOD.

Introductory remarks 192
Pancreatic digestion of milk 196
Modified casein or metacasein 198
Directions for the preparation of peptonised articles of food . . 200
  Peptonised milk 200
  Peptonised gruel 202
  Peptonised milk-gruel 203
  Peptonised soups, jellies, and blanc-manges 204
  Peptonised beef-tea 205
Nutritive value of peptonised food 206
Experimental evidence 207
Clinical experience of peptonised food 213
  In uræmic vomiting 214
  Gastric catarrh 214
  Crises of cardiac disease 214
  Pernicious anæmia 215
  Gastric ulcer 215
  Pyloric and intestinal obstruction 216
The use of pancreatic extract as an addition to food shortly before it is eaten 217
Pancreatic extract as an addition to nutritive enemata . . . 218

III.—THE USE OF MALT, AND ESPECIALLY OF MALT INFUSION, FOR THE PREDIGESTION OF STARCHY FOOD.

PAGE
Various kinds of diastase . . . 219
Conditions in which starch digestion is defective . . . 221
Preparations of malt . . . 222
Malt extracts . . . 223
Malt infusion . . . 224
Note on the antiseptic properties of chloroform . . . 225
Administration of malt preparations with food . . . 226
Predigestion of starchy food . . . 227
    Liebig's method . . . 228
    The use of malt infusion . . . 229
    Clinical experience . . . 230

SECTION IV.

DYSPEPSIA.

ON THE ACID DYSPEPSIA OF HEALTHY PERSONS.

General description . . . 335
Symptoms . . . 237
The acid residuum . . . 238
Nature and source of the acid . . . 239
Particular symptoms . . . 242
    Pain . . . 242
    Depression . . . 243
    Acid eructations and heartburn . . . 244
    Flatulence . . . 244
    Gastric cramp or paroxysmal pyrosis . . . 247
Diagnosis of acid dyspepsia . . . 249
Further incidents of acid dyspepsia . . . 250
Treatment . . . 250
    By antacids . . . 251
    By provoking salivation . . . 255

APPENDIX.

A MEMORANDUM ON THE GENERAL FEATURES AND THE MEDICAL ASPECTS OF THE OPIUM HABIT IN INDIA.

PAGE

Introductory—Euphoric agents 261
(1) The opium habit proper 263
  Distribution and prevalence 264
  Tolerance and susceptibility 269
  Age and sex 271
  Dosage 272
  Increase of dose and excess 274
  Stopping the opium habit 275
  The opium habit and food 277
  Effect on health and longevity 278
  „ „ insanity 281
  „ „ suicide 282
  Effect on the generative functions 284
(2) Opium as a household remedy in India 285
(3) Opium as remedy and prophylactic against malaria . . . 288
  Prevalence of malaria in India 290
  Composition of Indian opium 291
  Anarcotine as an antiperiodic 292
  Opium-eaters and malarial infection 294
  Plurality of malarial infection 296
(4) The practice of giving opium to infants 298
  Prevalence and dosage 299
  Why given 300
  General effect of the practice 301
  Opium marasmus 303
(5) Use of opium on occasions of ceremony 304
(6) Opium-smoking in India 310
  Madak-smoking 310
  Chandu-smoking 311
  Opium pipe 314
  Prevalence of opium-smoking in India 314
  Effect on health 315
  What the chandu-smoker inhales 316

INDEX 319

SECTION I

DIGESTION AND THE DIGESTIVE FERMENTS

SECTION I

DIGESTION AND THE DIGESTIVE [illegible]

SECTION I

DIGESTION AND THE DIGESTIVE FERMENTS

I.

DIGESTION IN GENERAL—THE DIGESTIVE FERMENTS—DIGESTION OF CARBOHYDRATES.

(*First Lumleian Lecture.*)

SUMMARY:—Digestion is a faculty or function common to animals and plants—Exterior digestion—Interstitial digestion—General characters and properties of the digestive ferments—Preparation of artificial digestive juices—Diastasic ferments and the digestion of starch—Theory of the process—The respective shares of saliva and pancreatic juice in the digestion of starch—When can starch be said to be fully digested?—Absolute energy of diastase—Digestion of cane-sugar and the inversive ferment.

DIGESTION has been usually regarded as the special attribute of animals. They receive into their alimentary canal the food which they require for their sustenance in a crude form. It is there subjected to the action of certain ferments which transmute its elements, by a peculiar chemical process, into new forms which are fitted for absorption. Looked at in this restricted sense, plants have no digestive function. They possess no alimentary canal, nor any vestige of a digestive apparatus. But when the matter is examined more profoundly it is seen that plants digest as well as animals, and that the process in both kingdoms of nature is fundamentally the same.

In order to understand this generalisation—which was first propounded by Claude Bernard, and constitutes one of the most important fruits of his splendid labours [1] —it is necessary to recognise digestion under two types or conditions—namely, a digestion which takes place exteriorly at the surface of the organism, and a digestion which takes place interstitially in the interior of the organs and tissues.

Exterior digestion is that common process with which we are familiar as taking place in the alimentary canal of animals, by which the crude food introduced from without is prepared for absorption.

Interstitial digestion, on the other hand, is that more recondite process by which the reserves of food lodged in the interior of plants and animals are modified and made available for the purposes of nutrition.

These two types of digestion are essentially alike both as regards the agents and the processes by which they are carried out—and although one type of digestion is more developed in the animal kingdom and the other type more developed in the vegetable kingdom, both types are represented in the two kingdoms—and bear witness to the fundamental unity of the nutritive operations in plants and animals.

I shall only be able to indicate in outline the facts and arguments on which Bernard sought to establish these propositions.

EXTERIOR DIGESTION.

We all know that the alimentary canal is simply a prolongation of the external surface; that the skin is continued, at either extremity, without a break, into the alimentary mucous membrane. Accordingly the processes which take place in the digestive tube are, strictly speaking, as much outside the body as if they took place on the surface of the skin. Upon this inner surface, if I may so call it, are poured out the digestive juices, charged with the ferments which are the special agents of the digestive processes. This is the common condition of exterior digestion as it occurs in animals—but it is not the only condition. Among some of the lowest members of the animal series a permanent alimentary canal does not exist. In the amœba any portion of the exterior is adapted for the reception of food. The morsel sinks into a depression formed on the surface at the point of impact—it is digested in this improvised stomach, and the indigestible portions are expelled through an improvised anus.

---

[1] Claude Bernard, *Leçons sur les Phénomènes de la Vie*, t. ii. Edited after his death by Dastre. Paris, 1879.

Among plants exterior digestion is a much less prominent feature than among animals, but examples of its occurrence and evidence of its importance are not difficult to point out. In the lowest orders of plants—fungi and saprophytes, which are devoid of chlorophyll—exterior digestion is probably a function of prime necessity. In all likelihood their carbon-containing food is only absorbed after undergoing a process of true digestion. The transformation of cane-sugar by the yeast plant is a striking example—though a distorted one—of exterior digestion. Cane-sugar is a crude form of food both to plants and animals, and requires to be transformed into invert-sugar (a mixture of equal parts of dextrose or grape-sugar and lævulose or fruit-sugar) before it can be made available for nutrition. The yeast plant is no exception to this rule; and when placed in a solution of cane-sugar it is under the necessity of transforming that compound into invert-sugar before it can use it for its profit in fermentation. This transformation is effected by a soluble ferment attached to the yeast cell, which can be dissolved from it by water. We shall see later on that a similar ferment exists for a similar purpose in the small intestine of animals—having the same property of changing cane-sugar into invert-sugar.

Even among the higher plants exterior digestion is not quite unknown. The function may be said to be foreshadowed in the excretion of an acid fluid by the rootlets of some plants which serves to dissolve and render absorbable the mineral matters in their vicinity. But genuine and most remarkable examples of this type of digestion occur among the so-called insectivorous plants, of which Mr. Darwin has given so interesting an account. In the sundews, the plant, by a peculiar mechanism provided on its foliage, seizes the insects which fortuitously alight on its leaves. A stomach is extemporised around the prey, into which is poured out a digestive fluid. The prey is digested, and the products absorbed, in essentially the same manner as in the gastric digestion of animals.

INTERSTITIAL DIGESTION.

Both animals and plants lay up reserves, or stores, of food in various parts of their tissues for contingent use, so that if you suddenly withdraw from them their food supplies neither animal nor plant immediately dies—it lives for a certain time on its reserves. But before these reserves can be made available for the operations of nutrition they must first be converted from their inert and mostly insoluble state into a state of solution and adaptability to circulate in the nutritive fluid which constitutes the alimentary atmosphere of the protoplasmic elements. This conversion of inert store-food into available nutriment is brought about certainly in some, presumably in all cases, by the same agents and processes as the digestion which takes place in the alimentary canal of animals; and it is this identity in the agents and the processes which Bernard insisted on as the proof of the fundamental identity of the two kinds of digestion.

The storing up of food is carried on to a larger extent in the vegetable than in the animal kingdom, owing to the intermittent life of most plants. In their seed, tubers, bulbs, and other receptacles are laid up stores of albumen, starch, cane-sugar, and oil—designed primarily for the growth and nutrition of the plant or its offspring—but which are largely seized on by animals and utilised for their food. Owing to their more continuous life animals store up food less than plants. Nevertheless, they accumulate stores of fat in various parts of their body—of animal starch (glycogen) in their livers and elsewhere—and of albumen in their blood. Birds also store up large quantities of albumen and fat in their eggs.

The transformation of store-food has been followed out most completely in regard to starch and its congener glycogen, and cane-sugar. Bernard worked out this subject with marvellous minuteness and success. It has long been known that the transformation of starch into sugar in germinating seeds was effected by diastase; and that a similar ferment, existing in saliva and pancreatic juice, performed the same office on the starchy food of animals. It has also been proved that the stores of starch laid up in the tuber of the potato and in various parts of other plants are changed at the periods of budding and growth in the same way and by the same agent. Bernard showed that animal starch or glycogen is stored up largely not only in the liver but in a variety of other situations, and especially that it is widely distributed and invariably present in large quantities in embryonic conditions. In juxtaposition with the glycogen is found a diastasic ferment which transforms it into grape-sugar, as it is required for the active operations of growth and nutrition.

The stores of cane-sugar which exist in the beet-root and in the sugar-cane are transformed or digested in like manner into invert-sugar when the plants enter on the second phase of their life—the phase of inflorescence and fructification. Here, again, it has been proved that the converting agent is a soluble ferment—the same ferment which, as already mentioned, is attached to the yeast cell—and the same ferment which exists in the small intestine of animals for a similar purpose.

The transformation of store proteids and fats has not been followed out with the same success as that of starch and cane-sugar. But the evidence, as far as it goes, and analogy, point to the conclusion that the stores of albuminous and oily matters contained in the seeds, bulbs, and other receptacles of vegetables are subjected to a digestive process before they are made available for the nutritive operations of the plants, and that the changes thus effected are of the same nature and accomplished by the same agents as those which take place in the digestion of proteids and fats in the alimentary canals of animals.

I have, I think, said enough to show the scope of the evidence and the analogies from which Bernard deduced certain far-reaching generalisations, which I have ventured to summarise in my own language in the following propositions:—

(1) Digestion, or the process by which crude food is changed into available nutriment, is a function or faculty of capital importance in every form of active life. (2) This function is exercised partly on food brought into proximity with the surface of the organism (exterior, chiefly intestinal digestion) and partly on reserves of food laid up in the interior of the organism (interstitial digestion). (3) The agents concerned in this function and their mode of action are essentially the same whether the organism be a plant or an animal—and whether the action take place in the interior of the tissues or on the general or intestinal surfaces.

GENERAL CHARACTERS AND PROPERTIES OF THE DIGESTIVE FERMENTS.

The essential work of digestion is carried out by a remarkable group of agents called soluble or unorganised ferments. These are found dissolved in the several digestive juices or secretions which are thrown out on the path of the food as it travels along the alimentary canal. The physical and mechanical processes to which food is subjected in the mouth and stomach are all purely introductory, or preparatory, and are solely intended to facilitate the essential work of digestion, which consists in the action of the digestive ferments on the alimentary principles.

The number of distinct ferments employed in the digestion of the miscellaneous food used by man is not accurately known, but there are at least seven or eight of them. The accompanying table presents in one view a scheme of the several digestive secretions or juices—and the ferments which they contain—together with an indication of the action of each ferment on the several alimentary principles.

Table of the Digestive Juices and their Ferments.

Digestive Juices	Ferments contained in them	Action on Food Materials
Saliva	Salivary diastase or ptyalin	Changes starch into dextrine and sugar.
Gastric juice	*a.* Pepsin	Changes proteids into peptones in an acid medium.
	b. Curdling ferment	Curdles the casein of milk.
Pancreatic juice	*a.* Trypsin	Changes proteids into peptones in alkaline and neutral media.
	b. Curdling ferment	Curdles the casein of milk.
	c. Pancreatic diastase	Changes starch into dextrine and sugar.
	d. Emulsive ferment	Emulsifies and partially saponifies fats.
Bile	?	Assists in emulsifying fats.
Intestinal juice	*a.* Invertin	Changes cane-sugar into invert-sugar.
	b. ? Curdling ferment	Curdles the casein of milk.

An examination of the table shows that a long and complicated series of ferment-actions is required to accomplish the digestion of our food. Starch is attacked at two points—in the mouth and in the duodenum—by two ferments, salivary and pancreatic diastase, which are substantially identical. Albuminous matters are also attacked at two points—in the stomach and in the small intestine—but here the two ferments, pepsin and trypsin, are certainly not identical. The ferment of which the only known characteristic is to curdle milk is found in the stomach and in the pancreas—and I think also in the small intestine. The bile is not known to possess any true ferment-action, but it assists, by its alkalescent reaction and by its physical properties, in emulsifying and promoting the absorption of fatty matters. The ferment which transforms cane-sugar, strange to say, is not encountered until the food reaches the small intestine.

The known digestive ferments all belong to the class of soluble or unorganised ferments. They are sharply distinguished from the insoluble or organised ferments, of which the type is yeast, in not having the power of self-nutrition and self-multiplication. All living organisms possess this power either in a dormant (potential) or in an active (kinetic) state. Soluble ferments cannot therefore be said to be alive—but they are exclusively associated with living organisms and take an essential part in their vital operations.

The digestive ferments are all the direct products of living cells, and may be regarded as detached repositories of cell-force. They are quite unknown in the domain of ordinary chemistry. Their mode of action bears no resemblance to that of ordinary chemical affinity, and has a distinctly physiological character. They do not derive their marvellous endowments from their material substance. They give nothing material to, and take nothing material from, the substance acted on. The albuminoid matter which constitutes their mass is evidently no more than the material substratum of a special kind of energy —just as the steel of a magnet is the material substratum of the magnetic energy—but is not itself that energy. This albuminoid matter of the ferment may be said to become charged, at the moment of elaboration by the gland-cells, with potential energy of a special kind—in the same way that a piece of steel becomes charged with magnetism by contact with a pre-existing magnet. The potential energy of the ferment is changed into the active form (*i.e.* becomes kinetic) when it is brought into contact with the alimentary substance on which it is designed to act.

The chemical and physical characters of the digestive ferments appear to be tolerably uniform. In composition they resemble proteid substances, and contain carbon, oxygen, hydrogen, and nitrogen in the same or somewhat similar centesimal proportions as albumen. But as not one of them has yet been obtained in a state of absolute isolation and purity, this is, strictly speaking, a matter of inference rather than an ascertained fact.

They are all soluble in water; they are all diffusible, though with great difficulty, through animal membranes and parchment paper. They are also capable (all those I have tried) of passing through porous earthenware by filtration under pressure; but some of them pass through readily, and others with the utmost difficulty and only in the smallest proportions.

They are precipitated from their watery solutions by absolute alcohol—but, unlike other proteids (peptones excepted), they are not truly coagulated by alcohol. When the alcohol is removed the ferments are still found to be soluble in water and to retain their activity unimpaired.

They are rendered permanently inert by the heat of boiling water; and when in solution they are coagulated and destroyed by a heat of about 160° Fahr. (71° C.).

There is a curious point in regard to the proteolytic ferments which requires elucidation. Liquid preparations of these ferments invariably contain a considerable amount of unchanged—that is to say of undigested—

albumen, which is precipitated by the addition of nitric acid or by boiling. This is the case both with pancreatic extracts and with solutions of pepsin acidulated with hydrochloric acid. It is evident that this substance cannot be any one of the ordinary forms of albumen—otherwise it would long since have undergone digestion—it would, in fact, have been transformed into peptone by the trypsin or pepsin associated with it in the solution—and in that condition would of course have been incapable of being precipitated by nitric acid or boiling. All this leads up to the inference that the albuminoid matter which constitutes the organic substratum of pepsin and trypsin is an altogether special form of albumen—and that one of its peculiarities is that it is unsusceptible of the proteolytic transformation which we call digestion. Its relation to ordinary albumens would resemble that of an unfermentable sugar in regard to ordinary sugars. It further suggests itself to one's mind that the undigested remnant which is invariably found as a residuum in the artificial digestions of proteids—and which goes by the name of 'dyspeptone'—is not, as has been thought, a by-product of the digestive process, but that it is simply an admixture of this variety of non-digestible albumen.

Each digestive ferment has its special correlative alimentary principle, or group of principles, on which alone it is capable of acting. Diastase acts exclusively on amylaceous substances. Pepsin and trypsin act only on the azotised principles—the emulsive ferment of the pancreas is only capable of acting on fatty bodies—the inversive ferment of the small intestine has no activity except on cane-sugar.

The changes impressed on alimentary principles by the digestive ferments are not, chemically speaking, of a profound character—and they affect much more the physical state of these principles than their chemical composition. In the main they are processes of deduplication and hydration—and the result is to render the substances operated on more soluble and more diffusible—to diminish their colloidal state and to make them approach or even to reach the crystalloid state. This does not appear to be invariable, however. Cane-sugar is a marked exception—it is converted in the small intestine into invert-sugar (a mixture of equal parts of grape-sugar or dextrose and fruit-sugar or lævulose), but invert-sugar, though more highly hydrated than cane-sugar, is neither more diffusible nor more soluble.

It does not appear to be absolutely true that all food requires digestion before it can be absorbed. Fat is largely taken up by the lacteals in its unaltered state—except in so far that it is finely divided or emulsified. Grape-sugar (dextrose) is not known to suffer any digestive operation, but to be absorbed unchanged. Perhaps it would be more correct to say that grape-sugar is an article of food predigested for us by the agency of plants.

Although the mode of action of digestive ferments is special and peculiar, the results of that action are not peculiar, but can be obtained in other ways by ordinary chemical forces. By long-continued boiling in water—and more rapidly by boiling with acidulated water—starch is converted into dextrine and sugar, and albumen is changed into a substance resembling peptone. The peculiarity of the action of ferments consists in this: that the ferments are able, swiftly and without violence, to produce changes which, by ordinary chemical agencies, can only be produced either by strong reagents or by long-continued and very slow action of weaker reagents.

It is interesting to remark that the changes produced in food by digestion are, in their ultimate results, very similar to, if not identical with, those produced by protracted cooking.

It is becoming evident that the active work which is prosecuted in many quarters on the action of ferments demands the introduction of some new words. The word ferment is still commonly applied to both organised and soluble ferments, although the necessity of referring these groups of agencies to separate categories is universally recognised. Kühne has proposed to designate the soluble ferments as 'enzyms,' and we may conveniently adopt the word into English, with a slight change of orthography, as 'enzymes.' May we not also designate the organised ferments as 'zymes ?' If this suggestion were adopted a great deal of paraphrase might be avoided by coining from these two roots the cognate words which we are in want of for clear expression and concise description.

The words ferment and fermentation have been so associated from old time with yeast and alcoholic fermentation that the application of the same words to the processes by which milk sugar is changed into lactic acid and alcohol into acetic acid, and to those more complex transformations which we call decomposition and putrefaction, appears strange to us. And yet it is now well known that all these transformations are produced by the action of minute organisms, and that they belong strictly to some category as alcoholic fermentation. Still more strange to us is it to apply the same terms to the silent transmutations which take place in the action of diastase on starch and the action of pepsin and trypsin on albumen.

If all organised ferments became known as 'zymes,' and all soluble ferments as 'enzymes,' then the process in which zymes are engaged might be called 'zymosis'—and the process in which enzymes are engaged might be termed 'enzymosis.' The action of the former might be described as 'zymic,' and that of the latter 'enzymic.' It would also follow that in scientific description the verb to 'ferment' would be displaced by the verb to 'zymose,' or to 'enzymose,' as the case might be.

THE PREPARATION OF ARTIFICIAL DIGESTIVE JUICES.

The study of the digestive ferments has been immensely facilitated by a method first introduced by Eberle. Eberle discovered that an aqueous infusion or extract of the digestive glands possessed the same properties as the natural secretions or juices of those glands. The reason of this is that the glands which secrete the digestive juices contain within them a reserve stock of their respective ferments. Accordingly, when the glands are infused in water their reserve stock of ferments passes into solution. These infusions or extracts then constitute artificial digestive juices which operate in a flask or beaker in the same way as the corresponding glandular secretions act in the alimentary canal. Solutions of organic matters are, however, extremely perishable—they pass quickly into putrefaction. In order to obviate this inconvenience, and to obtain an extract which is always handy for use, various preservative means have been employed. Bernard used carbolic acid—others have used glycerine[1] or common salt.

---

[1] Glycerine is one of the best solvents of the digestive ferments, especially for the preparation of solutions designed for experimental purposes. Bullock's *acid glycerine of pepsin* is used medicinally very largely, and is one of the most active preparations in the market.

These preservatives, although perfect for the purpose intended, have a pronounced taste which it is impossible to get rid of. I have made a good number of experiments on this point. As the ultimate object I had in view was to obtain a solution which could be administered as a medicine by the mouth—or which could be employed in the preparation of artificially digested food—I sought for a preservative which either had little taste and smell, or one which was volatile and could be got rid of by vaporisation. After a good many trials I adopted the three following solutions as on the whole the best suited for the purpose.

I. *Boracic Solution.*

This solution contains three or four per cent. of a mixture of two parts of boracic acid and one part of borax. An extract of the stomach or of the pancreas made with this solution keeps perfectly, and has little taste and no smell. For experimental purposes this extract is, I believe, all that can be desired—it is neutral in reaction and is chemically inert. It answers well also for administration by the mouth when the dose does not exceed one or two tea-spoonfuls. But when larger quantities are required for the preparation of artificially digested food, and when food thus prepared has to be used day after day in quantity sufficient to sustain nutrition, larger quantities of boracic acid and borax are taken into the stomach than that organ can always comfortably tolerate.

II. *Dilute Spirit.*

The second solution is water mixed with twelve or fifteen per cent. of rectified spirit.[1] This solution makes a most excellent extracting medium, and the quantity of spirit in it is so small as rarely to be an objection to its use. In the preparation of artificially digested food a final boiling is usually requisite, and in this final boiling the alcohol is dissipated. On the whole, this is the most generally useful of the three solutions.

---

[1] This proportion of spirit is not enough for perfect preservation in summer weather. The water should contain 20 to 25 per cent. of

III. *Chloroform Water.*

Chloroform dissolves in water in the proportion of about one in two hundred—these are the proportions employed in the preparation of the *Aqua Chloroformi* of the British Pharmacopœia. This forms a perfect solvent for the digestive ferments, and its keeping qualities are unrivalled. But though the quantity of chloroform dissolved is so minute (about two and a half drops in a fluid ounce), it communicates a somewhat powerful smell and taste to the solution. This taste and smell are agreeable to most persons, but not to all. It is, however, quite easy to get rid of the chloroform. If the dose to be used be first poured into a wineglass or saucer and left exposed to the air for three or four hours, the chloroform passes off almost entirely in vapour, and leaves behind a simple aqueous solution of the ferments. Or, if the solution is employed for the preparation of artificially digested food, the chloroform, being very volatile, disappears in the final boiling. It is perhaps well to mention that chloroform water has the property of reducing Fehling's solution, and that this property has to be taken into account in making experiments on digestion which involve testing for sugar.

rectified spirit. The solvent properties of the medium are not in the least deteriorated by this additional proportion of spirit—at any rate in regard to malt-diastase and the pancreatic enzymes.

Alimentary substances fall naturally into three well-marked groups, namely, *Carbohydrates*, *Proteids*, and *Fats*. I propose to consider the digestion of the three groups in the order here indicated. I have, however, no intention of dealing systematically with these subjects, but rather to take up certain points and questions in regard to which I have myself made observations, or which have a bearing on the preparation of artificially digested food and its administration to patients. I shall treat the digestive transformation of starch in some detail, because this has been worked out almost to completeness, and because it probably furnishes a type which will hereafter be of service as a guide to the study of the more complex problem of the digestion of proteids.

DIASTASIC FERMENTS—DIGESTION OF STARCH.

The importance of starch as an article of human food has, perhaps, scarcely been duly recognised. If we regard the enormous proportion in which the seeds of cereals and leguminous plants and the tuber of the potato enter into our dietary, and the immense percentage of starch in these articles, it is probably not too much to say that fully two-thirds of the food of mankind consists of starch.

In the raw state starch is to man an almost indigestible substance; but when previously subjected to the operation of cooking it is digested with great facility.

Diastase has only a feeble action on the unbroken starch granule, even at the temperature of the body. In the lower animals, and in germinating seeds, the starch granule is probably attacked in the first instance by some other solvent, which penetrates its outer membranes, and thus enables the diastase to reach and act on the starchy matter contained within. By the aid of heat and moisture in the process of cooking the starch granule is much more effectively broken up. Its contents swell out enormously by imbibition of water, and the whole is converted, more or less completely, into a paste or jelly or mucilaginous gruel. It is in this gelatinous form exclusively, or almost exclusively, that starch is presented for digestion to man.

The digestion of starch is accomplished partly by the saliva and partly by pancreatic juice, both of which are rich in diastase. Diastase also exists abundantly in the liver, and in smaller quantities in the intestinal juice, in the blood, the urine, and apparently in all the interstitial juices. Diastase from all these diverse sources appears to act substantially in the same manner on starch, changing it by a progressive hydrolysis into dextrine and sugar.

If the action of a fluid containing diastase—say saliva or extract of pancreas—on starch paste be watched, the first effect observed is the liquefaction of the paste and the production of a diffluent solution. This change is effected with great celerity—in two or three minutes the stiff paste becomes a watery liquid. This is evidently a distinct act—and antecedent to the saccharifying process which follows. By operating with small proportions of diastase and large proportions of pure starch paste it is possible to hit on a moment when liquefaction is complete and saccharification is not yet begun. At this moment the solution yields a pure starch reaction, and no reaction of dextrine nor of sugar. The process of saccharification follows immediately on the heels of liquefaction; and in ordinary manipulations the one process runs into the other.

The speed of the action depends primarily on the proportion of the diastase. By adjusting the proportions of diastase and starch in such degrees that saccharification will be completed in about a couple of hours the successive steps of the process can be leisurely followed by applying from time to time the appropriate tests.

If you test as soon as liquefaction is complete you get a pure blue with iodine and a slight reaction of sugar with Fehling's solution. In a few minutes the sugar reaction becomes more decided; and, although you still get a pure blue with iodine in the ordinary way of testing, you will get, by greatly diluting the blue solution and then adding more iodine, a deep violet tint—showing the presence of erythro-dextrine mixed with starch. The next step is the total disappearance of the blue reaction with iodine, and the substitution for it of an intense reddish-brown coloration of erythro-dextrine. By-and-by the reddish-brown colour is replaced by a yellowish-brown—indicating the preponderating presence of a different kind of erythro-dextrine. Meanwhile the sugar reaction goes on increasing. The next step is the entire disappearance of any kind of coloration with iodine. But the action is still very far from complete—the proportion of sugar goes on increasing for a considerable time after iodine has ceased to tint the solution. At length, however, matters come to a standstill, and the proportion of sugar ceases to increase.

The explanation of this series of reactions is impossible on the old view of the constitution of the starch. Until recently it was supposed that the starch molecule was represented by the comparatively simple formula $C_{12}H_{20}O_{10}$, and that under the influence of diastase this molecule was resolved by hydration into two molecules—one of dextrine and one of grape-sugar.

The researches of Musculus and O'Sullivan[1] have shown that this is not a correct account of the transformation. In the first place it was found that the sugar produced was not grape-sugar (dextrose), but another kind of sugar called *maltose*. It was also found that the dextrines first produced, and which were coloured red or brown by iodine, were progressively changed, with simultaneous production of sugar, into a series of dextrines of a lower type, which did not yield any coloration with iodine. To these latter kinds of dextrine the term achroo-dextrines has been applied.

As maltose is now ascertained to be the kind of sugar which is mainly produced in the digestion of starch by diastase, this body assumed a new and considerable importance in physiological chemistry, and it will not be out of place here to give some description of its properties. Maltose is a fermentescible, crystalline sugar of the saccharose (cane-sugar) class, having very little sweetening power, and possessing one atom less water than grape-sugar. Its formula is $C_{12}H_{22}O_{11}$. It possesses more rotatory power on polarised light than grape-sugar, but has considerably less power of reducing cupric oxide. The rotatory power of maltose is + 150, that of grape-sugar + 58. The reducing power of maltose is 61 compared to that of grape-sugar as 100. Maltose can be hydrolysed into grape-sugar by prolonged boiling with dilute acids. Malt-diastase does not possess this power, but we shall presently see that the diastasic ferments of the small intestine are able slowly to effect the same change.

---

[1] O'Sullivan's papers are published in the 'Journal of the Chemical Society' from 1872 to 1876. A full account of these researches is given in a paper in the same Journal for September, 1879, by H. T. Brown and J. Heron.

The researches of Musculus and O'Sullivan have rendered it necessary to assume that the molecule of soluble or liquefied starch is a composite molecule, containing several members of the group $C_{12}H_{20}O_{10}$—which is to be regarded as the constituent radical of the composite starch molecule. The starch molecule must in the future be represented by the formula $n(C_{12}H_{20}O_{10})$—the value of *n* not being yet definitely agreed upon.

Two able chemists of Burton-on-Trent, H. T. Brown and J. Heron, have extended these researches, and fully confirmed the main conclusions of Musculus and O'Sullivan. In an elaborate publication ('Journ. Chem. Soc.,' Sep., 1879) they have for the first time presented a fairly complete scheme of the succession of changes undergone by starch under the action of diastase. These chemists assume that the molecule of soluble starch consists of ten members of the group $C_{12}H_{20}O_{10}$, and that its formula should be written $10(C_{12}H_{20}O_{10})$. This view greatly facilitates the comprehension of the progressive hydrolysis of starch by diastase.

We have seen that starch in the condition of paste or jelly is distinguished sharply by its physical properties from liquefied or soluble starch. There is therefore in all probability some difference of molecular aggregation between starch in these two states—and it will not be a very bold assumption to suppose that starch in the gelatinous state consists of still more complex molecules than soluble starch—and that several molecules of soluble starch are grouped together to form the molecule of starch in the gelatinous state.

On the ground of these assumptions we may represent the successive steps of the digestion of gelatinous starch by the following series of equations.

The molecule of gelatinous starch is first resolved into its component molecules of soluble starch. The molecule of soluble starch is then resolved by progressive de-duplication and hydration into dextrine and maltose by the following succession of steps :—

One molecule of soluble starch

$$= 10(C_{12}H_{20}O_{10}) + 8(H_2O) =$$

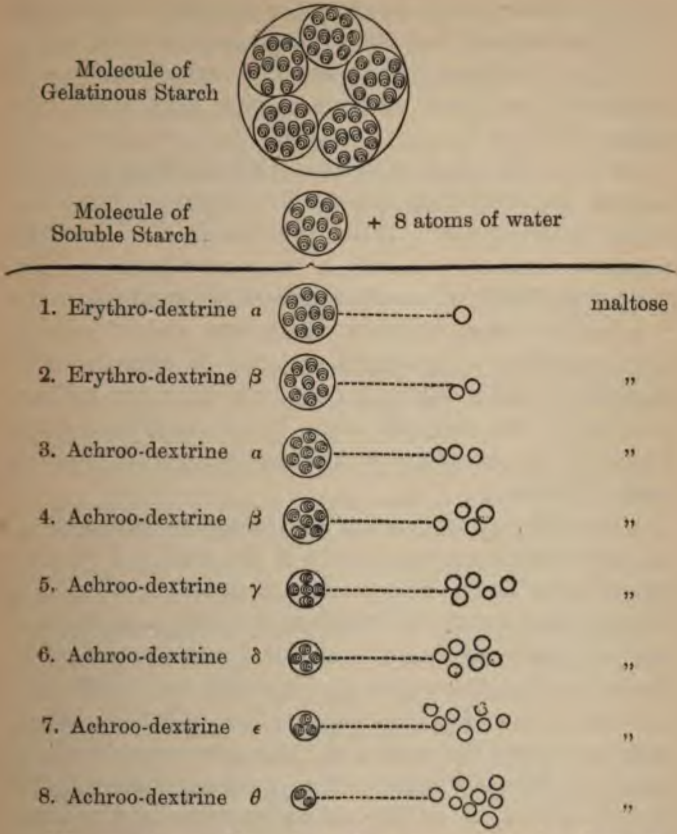
1. Erythro-dextrine α $9(C_{12}H_{20}O_{10}) + (C_{12}H_{22}O_{11})$ maltose
2. Erythro-dextrine β $8(C_{12}H_{20}O_{10}) + 2(C_{12}H_{22}O_{11})$,,
3. Achroo-dextrine α $7(C_{12}H_{20}O_{10}) + 3(C_{12}H_{22}O_{11})$,,
4. Achroo-dextrine β $6(C_{12}H_{20}O_{10}) + 4(C_{12}H_{22}O_{11})$,,
5. Achroo-dextrine γ $5(C_{12}H_{20}O_{10}) + 5(C_{12}H_{22}O_{11})$,,
6. Achroo-dextrine δ $4(C_{12}H_{20}O_{10}) + 6(C_{12}H_{22}O_{11})$,,
7. Achroo-dextrine ϵ $3(C_{12}H_{20}O_{10}) + 7(C_{12}H_{22}O_{11})$,,
8. Achroo-dextrine θ $2(C_{12}H_{20}O_{10}) + 8(C_{12}H_{22}O_{11})$,,

The final result of the transformation is represented by the equation

$$\underset{\text{Soluble Starch.}}{10(C_{12}H_{20}O_{10})} + \underset{\text{Water.}}{8H_2O} = \underset{\text{Maltose.}}{8(C_{12}H_{22}O_{11})} + \underset{\text{Achroo-dextrine.}}{2(C_{12}H_{20}O_{10})}.$$

In order to render this array of equations more easy of comprehension to those who are unaccustomed to read complex chemical formulæ, the transformation may be represented by the subjoined diagram.

We will assume that the molecule of gelatinous starch consists of an aggregation of five molecules of soluble starch, and that the molecule of soluble starch consists of an aggregation of ten groups of the radical $C_{12}H_{20}O_{10}$. Each of these radicals is represented in the diagram by the shaded dots. The open circles represent the atoms of maltose which are set free at each stage of the transformation. The first act is the breaking up of the large molecule of gelatinous starch into its component molecules of soluble starch. Then follows the progressive disintegration of the latter molecules into dextrine and maltose.



We must conceive that the energy of the ferment is exercised in gradually pulling asunder the component groups or radicals of the unstable molecule of soluble starch—detaching one after another from the parent molecule—each radical as soon as detached assuming an atom of water and becoming an atom of maltose. At each detachment the parent molecule draws its remaining groups together to form a new kind of dextrine. As the process goes on the dextrine molecule becomes smaller and smaller—that is, contains fewer and fewer component radicals—the higher dextrines giving a red or brown coloration with iodine, but the lower dextrines giving no reaction with iodine.

It is to be noted that after the transformation has reached its final term there still remains a portion of achroo-dextrine unconverted into maltose. Upon this remnant diastase has only a very slow action. The percentage result, when the reaction is completed, gives, in round numbers, 80 parts of maltose and 20 parts of achroo-dextrine. The eight varieties of dextrine indicated in the above table of equations have not all been obtained in the separate state, but there is strong evidence of the existence of at least several of them as distinct bodies.

The account just given of the transformation of starch has been deduced from a study of the action of diastase derived from malt. The question arises—physiologically an important question—whether the action of salivary and pancreatic diastase is identical with that of malt-diastase. The researches of Musculus and V. Mering[1] gave an affirmative answer to this question. These observers found that saliva and pancreatic extract act on starch paste in the same way as malt-diastase, the final products in all cases being achroo-dextrine and maltose, and not dextrose (grape-sugar). At my suggestion Mr. H. T. Brown was good enough to submit the question to a fresh examination in regard to pancreatic extract. His results fully confirm the conclusions of Musculus and V. Mering. He found, however, that there was a slight difference in the results when the action of pancreatic extract and malt-diastase on starch were continued a

[1] Maly's *Jahresbericht für Thier-Chemie for* 1878, p. 40.

long time. The pancreatic ferment, in addition to the power, which it shares with malt-diastase, of slowly converting the lowest achroo-dextrine into maltose, exhibited a power of slowly changing maltose into dextrose (grape-sugar) which is not possessed in any degree by malt-diastase. Mr. Brown also informs me that there is in the small intestine a ferment which possesses similar properties.[1]

THE RESPECTIVE SHARES OF SALIVA AND PANCREATIC JUICE IN THE DIGESTION OF STARCH.

The respective shares of saliva and pancreatic juice in the digestion of our farinaceous food is probably variable and perhaps not quite identical.

As all our farinaceous food is eaten after being cooked, the starch in it is more or less completely gelatinised ; it is, therefore, probable that one of the chief uses of salivary diastase in man is to liquefy starch jelly. A very brief contact suffices for this, and it is manifest that the accomplishment of this change is an important advantage in the subsequent operations in the stomach. Our gruels, blanc-manges, puddings, and similar farinaceous dishes owe their thick pasty condition to starch in the gelatinous state, and nothing can be imagined more resistent to the rapid permeation of a meal by the gastric juice, and to the pulping of it into a uniform chyme, than the presence of coherent masses of starch paste. If the saliva performed no other service than this, it would furnish an important aid to the digestion of a meal.

There has been considerable dispute as to whether, and how far, the saccharification of starch goes on in the stomach. My own observations lead to the conclusion that this depends on the degree of acidity of the contents of the stomach; and it is known that this varies within very wide limits. When a meal is swallowed it takes some time for the gastric juice to permeate the mass, and the acidity of the gastric contents is for some time feeble. As digestion proceeds the contents of the stomach tend to become more and more acid. This is a point which each one can observe for himself. The stomach is by no means reticent of its doings. The posseting which we see in infants goes on in a less degree in the adult; and we are perforce made aware, sometimes inconveniently so, by our palates, of the ascending scale of acidity in the stomach as digestion advances. Saliva acts energetically in neutral and in slightly acid media, but its activity is checked and finally arrested when the acidity becomes pronounced. When digestion is proceeding comfortably and normally a certain interval elapses before the acidity of the stomach becomes considerable, and during this interval the salivary diastase continues active, and has time to accomplish a good deal of work. But we must remember that our farinaceous food is, for the most part, not in the most favourable condition for rapid digestion. It is not generally in a state of mucilage—but in the form of a solid paste, as in bread, puddings, and pastry. A good deal of it, too, is imperfectly cooked. Consequently the larger part of our starchy food reaches the duodenum still unchanged, or only partly changed, and this larger part of the work is consummated by the pancreatic juice in the alkaline medium of the small intestine. I shall have to return to this point in speaking of gastric digestion.

---

[1] *See* a paper by Brown and Heron on the 'Hydrolytic Ferments of the Pancreas and Small Intestine' in the *Proceedings of the Royal Society for* 1880, p. 393.

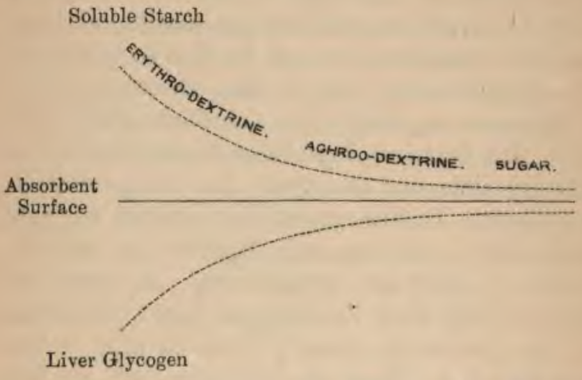
It has been noted as curious that the saliva of man possesses more diastasic power than that of almost any other animal. Among the herbivora, which are such large consumers of starch, the saliva has comparatively little diastasic power; and in some, as in the horse, it is almost or altogether wanting. I apprehend that this is due to the fact that man alone has learnt to cook his starchy food, and that the diastasic power of his saliva has become developed with the opportunity for its exercise. Diastasic power would be thrown away in the saliva of the horse, because he eats his food in the raw or uncooked state, and saliva is almost without action on raw starch.

WHEN CAN STARCH BE SAID TO BE FULLY DIGESTED?

Seeing that in the digestion of starch a number of intermediate products are evolved, the question arises—When can the digestion of starch be said to be accomplished? Is maltose the only product absorbed, or are not the dextrines, especially the achroo-dextrines, also absorbed? The dextrines, even those coloured by iodine, are highly diffusible, and pass freely through parchment paper in dialysis. In this respect they contrast strongly with starch jelly, and even with liquefied (or soluble) starch, both of which are undialysable. It seems not improbable that the lower dextrines are largely absorbed. Because if we follow the history of starch after it has been transformed by digestion, and absorbed, we are confronted with the remarkable fact that after absorption the products of starch digestion, or at least a large portion of them, undergo a reconversion in the liver into a substance closely resembling undigested starch. Glycogen, in its essential features, is an exact counterpart of soluble starch. It forms an opalescent solution in water; it is undialysable, and it is transformed by diastase into dextrine and sugar.

It appears reasonable to suppose that it would be an advantage to the economy if that portion of our starchy food which is destined to be stocked in the liver as glycogen should be absorbed at an early period of its digestion, because the less removed the digested product is from starch at the moment of absorption the fewer steps it will have to retrace in recovering the amylaceous state after absorption.

The annexed diagram will render my meaning clear. It represents, on one side of the dividing line of the absorbent membrane, the descending steps of the digestive process—and on the other side the ascending curve of the reconstructive process.



It is not necessary to suppose that the ascending steps of the reconversion are identical with the descending steps of digestion, but it is probable that they are fundamentally alike, seeing the close similarity of the products at the two ends of the journey. At any rate, there is no warrant in the present state of knowledge for the opinion that sugar is the only absorbable product of starch digestion.

ABSOLUTE ENERGY OF DIASTASE.

The notion that the energy of diastase is not consumed in action seems, on *à priori* grounds, to be quite untenable—such a notion contravenes a general principle in physics that energy in performing work is expended and finally exhausted. It is easy to show experimentally that diastase is no exception to this rule. Payen and Persoz estimated that malt-diastase was able to convert two thousand times its weight of starch into sugar. My own experiments with extract of pancreas indicate a much higher power than this. The following experiment illustrates at the same time the enormous diastasic power of pancreatic diastase and the fact that this power is strictly limited.

A quantity of starch mucilage was prepared, containing one per cent. of pure potato starch—100 cubic centimeters of this mucilage contained exactly one gram of dry starch. The pancreatic extract employed was prepared in the following manner :—Fresh pig's pancreas, freed from fat, was rubbed up with an equal weight of fine sand until it became a smooth uniform pulp. This pulp was spread out very thinly on sheets of glass, and allowed to dry in the open air for a fortnight. It was then scraped off with a knife and formed a rough shreddy sort of powder. 125 grams of this mixture of pancreas and sand were infused, at the temperature of the room, in 1,000 cubic centimeters of saturated chloroform water, with a little more chloroform added to ensure against decomposition. The mixture was allowed to stand for four days with occasional agitation, and the product was then filtered clear through paper. The extract of pancreas thus prepared proved a very serviceable preparation, and most of my observations on pancreatic digestion were made with it.

This extract was found to be so extremely active that it was necessary to dilute it largely in order to bring the quantities of starch operated on within due compass. Accordingly a dilution was made of one cubic centimeter of the extract in 1,000 cubic centimeters of water. Five numbered phials were then severally charged with 100 cubic centimeters of the prepared starch mucilage—so that each phial contained exactly one gram of dry starch. One cubic centimeter of the diluted pancreatic extract was added to phial No. 1—two cubic centimeters to No. 2—four cubic centimeters to No. 3—six cubic centimeters to No. 4—and eight cubic centimeters to phial No. 5. The phials were then corked and placed in the warm chamber, where the temperature was steadily maintained by a Page's regulator at 100° F. (38° C.).

At the end of twenty hours the contents of the phials were examined. All of them were perfectly transparent, and had entirely lost the opalescent appearance of the original starch mucilage, and not a vestige of sediment existed in any of them. The following reactions indicated the progress of the transformation.

No. 1 gave an intense blue coloration with iodine, and when the blue solution was largely diluted and more iodine added it developed a violet tint which showed the presence of erythro-dextrine; it also reduced the cupro-potassic solution freely.

No. 2 gave a strong blue reaction with iodine, and by diluting and adding more iodine the colour changed to a deep claret-red, indicative of abundance of erythro-dextrine. This and all the rest gave a strong sugar reaction with Fehling's solution.

No. 3 yielded no blue reaction with iodine, but an intense port-wine coloration of erythro-dextrine.

No. 4 gave no blue reaction with iodine, and only the faintest possible brown coloration with that reagent, showing only traces of erythro-dextrine.

No. 5 exhibited not a vestige of reaction with iodine. It contained neither starch nor erythro-dextrine, but it yielded a strong sugar reaction.

The transformation of No. 5 might be regarded as complete, but the rest still contained starch or erythro-dextrine, or both. Nos. 1, 2, 3, and 4 were restored to the warm chamber, and re-examined at the expiration of seven hours. No. 4 no longer gave the slightest reaction with iodine, but Nos. 1, 2, and 3 showed only slight signs of further alteration, and were returned to the warm chamber.

At the end of forty-eight hours from the commencement of the experiment, Nos. 1, 2, and 3 were examined again.

No. 1 showed a strong blue coloration with iodine, and also a strong reaction of erythro-dextrine.

No. 2 no longer gave any blue tint with iodine, but it exhibited an intense erythro-dextrine reaction.

No. 3 only gave a yellowish-brown reaction with iodine of moderate intensity.

After a further sojourn of seventy hours in the warm chamber the contents of the three phials were not found to be sensibly altered—they gave exactly the same reactions as before. It was evident that in these phials the diastasic action had run its course to an end within the period of forty-eight hours, and that the solutions had then come to a state of rest—the ferment had liberated all its energy—the limits of its power had been reached—and the task allotted to it was left unfinished. Nevertheless it had accomplished an amount of work which, considering its infinitesimally minute mass, appears marvellous. We shall now endeavour to measure approximately the amount of this work as indicated by the above experiments.

The original pancreatic extract, when evaporated to dryness on a water-bath, was found to leave a residue of 1·5 per cent. of organic matter. This organic matter included, besides diastase, a quantity of proteolytic ferment (trypsin) and a certain quantity of the milk-curdling ferment. It also included a certain quantity of digested proteid matter—for in making an extract of the pancreas there is always accomplished some self-digestion of the glandular tissue.

Taking into account these various admixtures, it would appear a very liberal allowance to estimate the diastasic ferment as amounting to one-fourth of the total organic matter. This would give us for the original extract a proportion of diastase in round numbers of 0·4 per cent., and for the diluted extract of 0·0004 per cent.

The proportion of diastase added to phial No. 4 seems to have hit off with precision the limit of quantity required to transform one gram (15·5 grains) of starch in forty-eight hours at a temperature of 100° F. (38° C.). The amount of diluted extract added to this phial was 6 cubic centimeters, and on the basis of the above estimate this represents a quantity of net diastase amounting to 0·00024 gram. This yields us by an easy calculation the astounding result that pancreatic diastase is able to transform into dextrine and sugar no less than 40,000 times its own weight of starch.[1]

---

[1] Marvellous as these numbers are, Mr. Horace Brown (whose joint paper with Mr. Heron, already referred to, has been my chief guide in

The speed at which a given quantity of starch is transformed by diastase depends essentially on the proportion of ferment brought to act upon it. In the above experiments the proportion of diastase was very minute in comparison with the amount of starch, and the action went on slowly for forty-eight hours. But if we reverse these proportions and mix a small amount of starch with a large amount of diastase, the transformation is instantaneously accomplished.

If a test-tube be half filled with an active extract of pancreas and a few drops of starch mucilage be quickly shaken therewith, you cannot detect the reaction of starch or dextrine in the mixture, however prompt you may be with the testing—the transformation has followed on the admixture as instantaneously as the explosion of the charge follows the fall of the trigger. Between these extremes there are all gradations. This mode of action differs entirely from what is seen in the operation of ordinary chemical affinity. If you add a drop of acid to an excess of alkali, the acid is instantly neutralised and the action comes to an end; and, conversely, if you add a drop of alkali to an excess of acid, the action is equally instantaneous; the affinity of the two bodies for each other is a mutual affinity. But this is not the case with the action of diastase on starch. The starch appears to be entirely passive in the process; all the energy is on the side of the diastase, and this energy can only be liberated gradually. There is something in this strikingly suggestive or reminiscent of the action of living organisms. To illustrate my meaning, let us compare the

---

trying to work out the theory of starch digestion) informs me in a private communication that he has arrived at numbers still more wonderful in estimating the transforming power of malt-extract on the higher dextrines.

particles of the ferment to a band of living workmen whose function is to scatter little heaps of stones. If the heaps are few and the workmen many, all the heaps will be scattered at once, and the energy of the workmen will still remain sensibly unimpaired. But if the heaps are millions and the workmen hundreds, and if the workmen are doomed to labour on until they fall exhausted at their task, the scattering of the heaps will go on for a comparatively long time and the process of exhaustion will be a gradual one.

I may here mention that the diastasic ferment does not exist in the saliva and pancreatic juice of young suckling animals—except in minute proportions. Its quantity increases when the teeth are cut. In the human infant diastase does not appear to exist in sufficient abundance to digest starchy matters effectively until about the sixth or seventh month. Until this period it is therefore not advisable to administer farinaceous food to infants.

DIGESTION OF CANE-SUGAR—INVERSIVE FERMENT.

Bernard[1] first called attention to the fact, already mentioned, that cane-sugar (saccharose) required digestion both in animals and plants before it could be used in nutrition. The cane-sugar stored up in beet-root and in the sugar-cane is changed by ferment-action into invert-sugar before it is permitted to circulate in the sap and take part in the nutritive operations of the plant. He found also that an analogous transformation was requisite before cane-sugar could be assimilated by animals. He states that when cane-sugar is injected into the blood it circulates therein as an inert body, and is in no degree used as nutriment by the tissues, but is eventually entirely removed, unchanged, with the urine. Cane-sugar is, however, an important article of food, and is consumed by us in large quantities every day. And we know that when thus consumed it does not behave like an inert matter—circulating awhile in the blood, and then being eliminated by the kidneys as a waste product. It is evidently absorbed and assimilated, and must therefore, somewhere or other, be transformed or digested in animals as it is in plants. Reasoning in this way, Bernard sought for an inversive ferment for cane-sugar in the alimentary tract; and after searching in the saliva, in the stomach, and in the pancreas in vain, he at length discovered it in the small intestine. In the small intestine he found that cane-sugar was transformed into invert-sugar, and by a similar ferment with that destined for analogous purposes in yeast, in beet-root and in the sugar-cane.

---

[1] Claude Bernard, *Leçons sur les Phénomènes de la Vie*, t. ii., p. 36. Paris, 1879.

The transformation of cane-sugar into invert-sugar is represented by a very simple equation :—

$$\underset{\text{Saccharose.}}{2C_{12}H_{22}O_{11}} + \underset{\text{Water.}}{2H_2O} = \underset{\text{Dextrose.}}{C_{12}H_{24}O_{12}} + \underset{\text{Lævulose.}}{C_{12}H_{24}O_{12}}$$

The inversive ferment was detected by Bernard in the small intestine of dogs, rabbits, birds, and frogs. Balbiani found it in the intestine of the silk-worm. It was recognised by myself in an extract of the small intestine of the pig, the fowl, and the hare. It does not exist in the large intestine.

But although my observations on this subject coincided in the main with those of Bernard, I noted two points which I think merit further attention. The first was that while a piece of small intestine infused in water yielded a mixture which was capable of inverting cane-sugar, the same infusion when filtered through paper until it was perfectly clear had no such power. It seemed as if the inversive ferment did not pass freely, if at all, into true solution, but remained attached to some of the formed elements contained in the intestine. The second point I noticed was the extreme slowness of the action. When cane-sugar was added to the unfiltered infusion of intestine, and the mixture maintained at blood heat, it generally took a couple of hours before a reducing effect with the copper test could be obtained. Both these circumstances reminded one of the action of formed ferments, and I could not help thinking that there was here something which required clearing up at some future time.

II.

DIGESTION OF PROTEIDS—THE MILK-CURDLING FERMENT—THE EMULSIVE FERMENT.

(*Second Lumleian Lecture.*)

SUMMARY:—Pepsin and trypsin and the digestion of proteids—Nature of the acid of gastric juice—Effect of gastric juice on the salivary and pancreatic ferments—Digestive proteolysis—Characters of peptones—Comparison of the action of pepsin and trypsin—Peptogens—The milk-curdling ferment—The emulsive ferment and the digestion of fats.

PEPSIN AND TRYPSIN—DIGESTION OF PROTEIDS.

VARIOUS kinds of albuminous or proteid substances are used by mankind as food. The most important of these are muscular flesh, the casein of milk, and egg-albumen from the animal kingdom—and gluten, albumen, and legumen from the vegetable kingdom.

Proteids are attacked by the digestive ferments at two points in the alimentary canal, by pepsin in the stomach, and by trypsin in the small intestine. Between these two acts of digestion there is a complete break in the duodenum, owing to the abrupt change of reaction from acid to alkaline which occurs at that point.

Gastric digestion is, in all creatures, an essentially acid digestion; but the most varied opinions have been entertained as to the nature of the acid. It has been supposed in turn to be hydrochloric acid, lactic acid, acid phosphate of lime, butyric, and even acetic acid.

Much of this confusion has arisen from not distinguishing between the acid of pure gastric juice as secreted into an empty stomach and the acid of the gastric contents during the digestion of a meal. A good deal of light has been thrown on this subject by the recent researches of C. Richet.[1] This observer found himself in exceptionally advantageous circumstances for the study of the gastric juice. He had under observation a young man on whom Verneuil had successfully performed the operation of gastrotomy for the relief of impermeable stricture of the œsophagus, the result of swallowing inadvertently a quantity of caustic potash. The complete occlusion of the œsophagus enabled Richet to obtain and examine the gastric juice in a pure state, uncontaminated with saliva. All food had to be administered through the fistulous opening left after recovery, and the observer could at any moment—as in the famous case of Alexis St. Martin—withdraw portions of the gastric contents for examination. Richet also took advantage of the new method of separating the various organic and mineral acids from one another made public by Berthelot in 1872.[2]

Berthelot had found that, if you shook up an aqueous solution of any acid with ether, and then allowed the two fluids to separate, a part of the acid passed into the ether, and that the remainder clung to the water, and that the ratio between these two parts was a constant quantity. He called this ratio the *coefficient of partage*, and found that its value was a fixed characteristic for each particular acid. Solutions of the mineral acids were found to yield nothing, or almost nothing, to ether when agitated with it—but organic acids were found to pass into the ether in considerable, though very variable, quantities—the proportion varying in a constant ratio according to the nature of the acid.

---

[1] *Du Suc Gastrique*, by Ch. Richet. Paris, 1878.

[2] *Ann. de Chimie et de Physique*, 4^e^ série, t. xxvi., p. 396.

Testing pure gastric juice, uncontaminated with food or saliva, by this method, Richet found that almost all the acid was retained by the water, and that only a small proportion—about one in twenty-two—passed into the ether. This showed that the acid of pure gastric juice was almost entirely a mineral acid, with only a minute admixture of organic acid. The organic acid (tested by the same method) exhibited a coefficient of partage closely corresponding with that of sarcolactic acid. The nature of the mineral acid was determined by a method similar to that employed by C. Schmidt, and yielded the same result—namely, undoubted evidence that the mineral acid of pure gastric juice was hydrochloric acid. But Richet found that this mineral acid did not behave in the presence of salts of the organic acids quite in the same way as free hydrochloric acid does. The observations of Berthelot had shown that when free hydrochloric acid is added to a solution of acetate of soda, or other similar organic salt, the mineral acid attaches the base entirely to itself, and throws the whole of the organic acid free into solution—so that the mixture when tested by the method of coefficient of partage behaves exactly like an unmixed solution of the organic acid. When pure gastric juice was put to this test it was found that, although it liberated the organic acid largely, it did not do so to the same extent, by a good deal, as if the mineral acid contained in it had been entirely free. It behaved, rather, as hydrochloric acid does when united with a feeble organic base, such as leucin or peptone—and, on the ground of what appear to be very careful experiments, Richet came to the conclusion that this feeble base was probably leucin, derived from the gastric mucus, and that the acid of pure uncontaminated gastric juice was hydrochloric acid in loose combination with leucin.[1]

Richet next proceeded to examine the free acid actually existing in the stomach during the digestion of a meal in his patient with gastric fistula. He found, as might have been expected, that this differed from the acid of pure unmixed gastric juice—in this respect, namely, that it contained a very much larger proportion of organic acids, in comparison to the mineral acid, than pure gastric juice. It was evident that the mineral acid had to a large extent seized upon the bases of the acetates, malates, lactates, butyrates, and other organic salts always present in the food, and had set free their organic acids. The real work of digestion, then, so far as the acid constituent is concerned therein, is largely performed by various organic acids thus set free from the articles of food which are undergoing digestion.

Richet found that the acidity of the contents of the stomach during digestion, although it varied through considerable limits, had a marked tendency to maintain the normal average. If acid or alkali was added to the digesting mass the mean was presently restored automatically—the stomach in the former case ceasing to secrete acid, and in the latter case secreting an increased quantity of acid.

---

[1] There are other proofs that the acid of the gastric juice is not free hydrochloric acid. It was shown by Bernard that free hydrochloric acid, even in the proportion of one in a thousand of water, dissolves oxalate of lime—but gastric juice possesses no such power. Blondlot likewise proved that gastric juice does not decompose carbonate of lime—whereas the feeblest dilutions of free hydrochloric acid do so.

THE EFFECT OF GASTRIC JUICE ON THE SALIVARY AND PANCREATIC FERMENTS.

The observations of Berthelot on the power of a mineral acid to set free the acids of organic salts, and to take their place with the bases—and the further observations of Richet, showing that the acids actually free in the gastric contents during digestion were organic acids, have led to the re-examination of a point of some importance, namely—as to whether the salivary and more especially the pancreatic ferments were or were not destroyed by the acid contents of the stomach. The matter has a practical interest in this way. If the gastric acid destroys these ferments, it is evidently useless to administer pancreatic preparations by the mouth during digestion, because they would be rendered inert by the acid contents of the stomach. On the other hand, if they are not destroyed in passing through the stomach, but merely lie dormant and recover their activity in the alkaline medium of the small intestine, then we can administer pancreatic preparations during digestion with every prospect of their passing uninjured through the pylorus and proving useful in assisting digestion in the small intestine.

A series of experiments bearing on this question were submitted by T. Defresne to the Académie de Médecine and the Académie des Sciences towards the close of 1879, and have attracted some attention. On the ground of the experiments Defresne arrived at the following conclusions—namely, that saliva continued its action on starch in the stomach without interruption—that the pancreatic ferments in like manner preserve their activity in the presence of the gastric acid—that the acids of the chyme, being organic acids, did not really destroy these ferments, but merely reduced them to a state of temporary inertness; so that when the acidity of the chyme was neutralised in the duodenum they recovered their powers and exhibited undiminished activity both on starch and proteids.

As the question had a direct bearing on the medicinal administration of pancreatic preparations, and indirectly on the administration of malt-diastase and malt-extract, I thought it desirable to repeat some of Defresne's experiments, and to put the question raised by these experiments to the test in other ways.

One of Defresne's (apparently) most convincing experiments was the following, which I give nearly in the words of the abstract of the paper published in the 'Proceedings of the Académie de Médecine' for Nov. 4, 1879. When 20 grams of dilute hydrochloric acid, having twice the acidity of the normal chyme (which is estimated as 2 per 1000 of HCl), are mixed with 20 grams of egg-albumen—what follows? The acidity of the medium is no longer due to free hydrochloric acid, but to the lactic and phosphoric acids of the white-of-egg which have been set free. In presence of these acids pancreatine may be digested for two hours in the warm chamber with impunity. And if, at the end of this period, the acidity of the mixture be neutralised, digestion is accelerated and the pancreatine peptonises 38 times its weight of albumen.

I repeated this experiment in the following manner: 40 grams of boiled and chopped white-of-egg were mixed with 40 cubic centimeters of dilute hydrochloric acid of the strength of 4 per 1000. This mixture was subjected to a preliminary digestion of two hours in the warm chamber at 40° C. The object of this preliminary digestion was to allow the hydrochloric acid a sufficient time to seize on the bases, and to set free the organic acids of the white-of-egg. At the end of this time 5 cubic centimeters of an active extract of pancreas were added to the mixture. A second experiment was arranged in exactly the same way, except that filtered saliva was substituted for extract of pancreas. The mixtures were kept in the warm chamber for a further period of one hour, and were then filtered and carefully neutralised. On testing the neutralised filtrates, I obtained approximatively the same results as Defresne. The diastasic and proteolytic ferments of the pancreatic extract were found active, but not so active by a good deal as if the extract had been diluted to the same extent with simple water. In the second experiment with the filtered saliva, the ptyalin had preserved its activity quite unimpaired.

These experiments, however, involve a fallacy which vitiates the deductions intended to be drawn from them. White-of-egg has a highly alkaline reaction, and although the acid used in the experiment possessed double the strength of the normal gastric juice, it was found that the mixtures, at the end of two hours' digestion, had only a comparatively feeble acidity—in fact, only one-seventh of the normal acidity of the gastric contents. It has long been known that the salivary and pancreatic ferments are able to resist a feeble acidity, but the question really at issue is: Can these ferments resist the average acidity of the contents of the stomach, when, moreover, this acidity is rendered still more destructive to them by the presence of pepsin?

I tested the question in this way. A distinction is drawn, and rightly, between acidity due to free hydrochloric acid, and a similar degree of acidity due to an organic acid. Now, lactic acid is a typical organic acid, and it is also an acid which is often, if not always, present in the contents of the stomach during digestion. I prepared a solution of lactic acid corresponding in saturating power to the normal gastric acid (2 per 1000 HCl). To 50 cubic centimeters of this dilute lactic acid I added 5 cubic centimeters of a solution of pepsin and 5 cubic centimeters of an active extract of pancreas. I prepared a second similar experiment, but substituted filtered saliva for pancreatic extract. The mixtures were then placed in the warm chamber for one hour. At the end of this period the solutions were exactly neutralised and tested. They were both found to be absolutely inert. Not a vestige of amylolytic nor proteolytic power had escaped destruction.

I had an opportunity of trying the same question in a still more satisfactory way. While I was examining the throat of a patient suffering from an ailment which did not affect his general health, a portion of the contents of the stomach was ejected, and fortunately caught in a clean vessel. This was immediately filtered, and about 10 cubic centimeters of clear acid solution were obtained. The period of digestion was three hours after breakfast. One half of this was devoted to testing its saturating power. It was found to possess an acidity very nearly corresponding with that of normal chyme. To the remaining portion five drops of extract of pancreas and five drops of filtered saliva were added, and the mixture was placed in the warm chamber for one hour. At the end of this time it was exactly neutralised, and divided into two equal portions. One portion was tested with a drop of starch-mucilage, and found to be absolutely devoid of amylolytic power. The other portion was added to an equal volume of milk rendered slightly alkaline with bicarbonate of soda, and was then placed in the warm chamber. Not the slightest digestive action was produced on the milk in twelve hours.

I may mention that in the above experiments I used milk as the test of proteolytic activity. I had become thoroughly familiar with the behaviour of milk with pancreatic preparations during a long course of observations, and was therefore able to detect the slightest signs of pancreatic action.

With this evidence before me, I am unable to accept the conclusions of Defresne and others in Paris who allege that saliva and pancreatic preparations can resist the normal acidity of the stomach in full digestion, and who recommend the administration by the mouth of pancreatic preparations during the period of chymification. I will in my next lecture point out the time and the method in which these preparations may, I believe, be administered by the mouth with some prospect of success.

DIGESTIVE PROTEOLYSIS.

The changes undergone by albuminoid substances in digestion are still very imperfectly understood. It is, however, known that the chief end-product of the transformation is peptone. It is also known that between any native proteid—egg-albumen, muscle-fibrin, casein, or legumin—and the end-product peptone there are intermediate grades and by-products which have hitherto proved difficult to define and isolate. The constitution of the proteid molecule is still unknown to chemists. That it is a highly complex aggregation is certain; and it can scarcely be doubted that the way to a better knowledge of its constitution lies in a persevering study of the action on it of the digestive ferments. It has been already seen that in the case of starch the action of diastase furnished the key to the constitution of the starch molecule—and, similarly, it is not unreasonable to expect that the mystery of the proteid molecule will be finally solved by a study of the action on it of pepsin and trypsin. Attention has hitherto been too exclusively directed to peptic digestion, which is complicated by the inter-action of an acid. Pancreatic digestion is, in this respect, a simpler process—inasmuch as it requires the interference neither of an acid nor of an alkali, but is a reaction, pure and simple, between the ferment and the proteid. This, however, is a question of the future.

Characters of Peptones.—The end-product peptone has been fairly isolated and its characteristics defined. If the filtered product of a pancreatic digestion of egg-albumen be evaporated to dryness in a watch-glass at a temperature of 104° Fahr. (40° C.) there remains a glassy straw-coloured residue resembling dried gum. With the point of a penknife this can be chipped off in shining scales, which may be easily reduced to a fine whitish powder—this is nearly pure peptone. This substance is extremely soluble in water: and its solutions, even when highly concentrated by evaporation, betray no jellying, and no viscosity, but continue diffluent almost to the moment of desiccation—only just before drying up do they assume a slightly syrupy consistence. When the latter point is approached the solution deposits beautiful white crystalline sheaves of tyrosin and spheres of leucin. From the constancy with which these crystalline bodies make their appearance in pancreatic digestion it may be inferred that they constitute an essential portion of the final products of the transformation.

The reactions of peptone are mostly of a negative character. Its solutions give no precipitation with nitric acid, nor with boiling, nor with ferrocyanide of potassium and acetic acid. The behaviour of peptone with alcohol is peculiar. When a strong peptone solution is dropped into absolute alcohol the peptone is precipitated as a white sediment, but it is not truly coagulated into an insoluble modification, as all the other proteids are, for when the alcohol is removed the deposit is found to have preserved its solubility in water—even after prolonged contact with the alcohol. Solutions of peptone are precipitated by those metallic salts which throw down other proteids, also by tannin when the solutions are neutral. When the solutions are rendered alkaline, the cupro-potassic test (Fehling's solution, added in very small quantity) produces a rose-red coloration, whereas other proteids produce a violet tint. Physiologically, by far the most important reactions of peptone are its extreme solubility in water and its diffusibility through organic membranes. With regard to the latter point, contradictory statements have been made by different investigators. Otto Funke rated the diffusibility of peptone through the membrane of the small intestine higher than that of common salt. On the other hand, V. Wittich concluded that peptones did not pass through parchment paper more rapidly than unaltered albumen. My own observations support the view that peptone is incomparably more diffusible through parchment paper than the native proteids. In the case of milk the effect of digestion is very marked in regard to its behaviour in the dialyser. When milk was dialysed for forty-eight hours into twice its volume of water, not a trace of proteid matter could be detected in the diffusate; but when milk had been previously digested for a couple of hours with pancreatic extract, an abundant reaction with tannin and Fehling's solution was obtained after dialysing it for eight hours.

My results with egg-albumen were equally striking. I prepared a solution by agitating white-of-egg with nine times its bulk of water, and straining the product through muslin. When this solution was dialysed into twice its volume of water for thirty-two hours it yielded absolutely no reaction with tannin nor with the cupro-potassic test. But when the same solution was previously digested, either with pepsin and acid or with pancreatic extract, and then dialysed, it gave in five hours a slight but distinct reaction, both with tannin and with Fehling's solution, and in sixteen hours a most abundant reaction.

The theoretical views held by physiologists in regard to the intimate nature of the transformation undergone by proteids in the presence of pepsin and trypsin are still unsettled, but recent opinions converge towards the idea that the process is, in the main, one of progressive de-duplication with hydration, similar in type to the transformation of starch by diastase. This view receives a positive support from the recent analyses of Henninger. By operating on highly purified albumen, fibrin, and casein, Henninger[1] succeeded in obtaining peptones in a state of great purity. An analysis of peptones so obtained indicated that they contained less carbon and nitrogen, and proportionately more hydrogen, than their original proteids. The differences were, it is true, small, but they pointed distinctly in the direction of the conclusion that there was a fixation of the elements of water by the proteid in the course of its transformation into peptone.

Henninger also believes that he has succeeded in reversing the process, and in reproducing an albuminous substance from peptone by operating on it with dehydrating agencies. He found that when fibrin-peptone was heated with anhydrous acetic acid at 80° C., or was maintained for an hour at the temperature 160° to 180° C., it yielded a body which agreed closely in its reactions with syntonin.

---

[1] A. Henninger, *De la Nature et du Rôle Physiologique des Peptones.* Paris, 1878.

The intermediate products which are generated in the course of proteid digestion, and stand between the original proteid and the end-product peptone, are very imperfectly understood. The laborious researches of Meissner and Kühne have shown that several such intermediate bodies are produced, but these have not yet been adequately isolated and defined.

COMPARISON OF THE ACTION OF PEPSIN AND TRYPSIN.

The action of pepsin and trypsin, although similar in the main results, is certainly not identical. There is a markedly larger production of leucin and tyrosin in tryptic than in peptic digestion. Moreover, the action of the two ferments on different proteids appears to vary both in character and in energy. Milk is much more readily digested by pancreatic extracts than by artificial gastric juice; but in the case of egg-albumen the advantage lies decidedly with the gastric juice. The study of the digestion of egg-albumen by the two methods yielded some interesting results. I employed for this purpose a dilution of egg-albumen (obtained from *fresh-laid* eggs) with water, in the proportion of one in ten. This remains uncoagulated after being boiled in the water-bath, and furnishes a favourable medium for studying the digestion of albumen—more favourable in some respects than the chopped boiled white-of-egg usually employed. It permits the ferment to be at once brought into uniform and intimate contact with the particles of the albumen, thus obviating the irregularity and want of constancy which necessarily attends the operation of a solvent acting on solid pieces of variable size, which can only be attacked progressively from their surfaces. In the raw state this solution is digested with extreme slowness by artificial gastric juice; and pancreatic extract is nearly inert on it; but after being boiled it is attacked with energy by both the gastric and the pancreatic ferments.[1] When the boiled solution was treated, in the warm chamber, with pepsin and hydrochloric acid, the transformation of the albumen went on rapidly and without interruption to its close. In the earlier periods of the action the mixture gave a dense precipitate with nitric acid and with ferrocyanide of potassium; but this precipitation became progressively less and less pronounced, until at the end of two or three hours these reagents only produced a slight haze. The albumen was now completely digested, or at least as nearly so as could be reached, for this remnant of a reaction persisted even after a further digestion of twenty-four hours.

When the same solution was treated with pancreatic extract the progress of events was different. For an hour or two (the time varying with the quantity of extract added) there was no apparent change—but at the end of this time the mixture lost its diffluent condition, and became converted into a gelatinous mass exactly resembling a thin starch jelly. By-and-by the gelatinous matter broke up into little masses, which floated in a transparent liquid. At this point the action seemed to be arrested. The floating masses of jelly remained almost undiminished in quantity after twenty-four and even forty-eight hours. When the mixture was filtered the liquid portions came through perfectly transparent, and the jelly-like matter was left on the filter. The filtrate was found to be a rich and nearly pure solution of peptone—uncontaminated with any undigested or half-digested albumen. The jelly-like matter was found to be insoluble in water, hot or cold, but it dissolved readily in acids, and was rapidly digested by pepsin and hydrochloric acid.

---

[1] In cooking this solution it is advisable to use the water-bath, for otherwise some of the albumen coagulates and cakes on the bottom of the vessel, and the liquid froths up in an inconvenient manner. If the eggs from which the albumen has been obtained are not freshly laid some coagulation will occur on boiling the solution. The addition of a drop of ammonia obviates this.

If a large amount of pancreatic extract was used a considerable proportion of the jelly-like matter was slowly dissolved—but the main result was always the same—the pancreatic ferment was only able to convert a part of the albumen into peptone, whereas the gastric ferment converted the entire quantity, with the exception of an insignificant residuum.

In the case of milk the relation of the two ferments is reversed. Tryptic digestion of milk is rapid, and leaves only a very slight residue—whereas peptic digestion is slow, and leaves a large residue. I have some further observations to make on the digestion of milk by trypsin, but it will be more convenient to take up the subject when I come to the use of pancreatic extract for the preparation of artificially digested food.[1]

The primary function of the pepsin acid of gastric juice is evidently to get the albuminoid matters into solution rather than to peptonise them. Bernard ranked pepsin low as a peptonising agent. He looked on gastric digestion as a hasty preparatory process, introductory to the more perfect intestinal digestion. This seems to me a truthful view. The rapidity with which boiled egg-albumen is dissolved by an active preparation of pepsin is very striking—but the matter in solution is not, as is well known, really digested—it is merely liquefied, and is nearly all re-precipitated by neutralisation. The later stages of digestion—those which approach or reach up to peptone—appear to be performed by pepsin very slowly and as it were with difficulty. The case is quite otherwise with trypsin. The action of trypsin on solid albuminoid masses is exceedingly slow and imperfect—but its action on liquid casein, as it exists in milk, is marked by a rapidity and completeness of which there is no parallel example in the case of pepsin.

---

[1] Most observers have noticed the occurrence of this indigestible residuum (named *Dyspeptone* by Meissner) in the artificial gastric digestion of proteids. I have noticed the same in the digestion of milk by pancreatic extract.

PEPTOGENS.

I may here advert to a singular view advanced by Schiff in regard to the production and secretion of pepsin and trypsin. Schiff found that when an insoluble aliment such as boiled white-of-egg (or fibrin, or meat which had been deprived of its soluble portions) was introduced into the stomach of a fasting animal no pepsin was secreted, and the albumen remain undigested; but if with the albumen certain soluble aliments were introduced into the stomach, then pepsin was produced, and digestion immediately began.

To these substances, which had the power of provoking the formation and secretion of pepsin, Schiff gave the name of *peptogens*. Among the most effective peptogens were found to be solutions of dextrine, extract of meat (or soup), infusion of green peas, bread (which contains dextrine), gelatin, and peptones. On the other hand, solutions of grape-sugar, soluble starch, fat-emulsion or gum had no peptogenic effect; and milk and coffee had not much. Schiff further found that peptogenic substances were just as effective when they were injected into the blood, or into the cellular tissue, or introduced as enemata into the rectum, as when they were introduced directly into the stomach. On the other hand, when peptogens were injected into the small intestine their influence was not observed—their effect seemed to be annulled by some action of the mesenteric glands, or by some change induced in them in their passage along the thoracic duct.

On the ground of these experiments—and they were numerous and oft repeated, and gave constant and decisive results—he concluded that the absorption into the blood of these soluble aliments was a necessary preliminary of proteid digestion—that no pepsin nor trypsin was secreted unless these substances existed beforehand in the blood. The first act, according to Schiff, of gastric digestion was the absorption from the constituents of a meal of these soluble peptogens by the veins of the stomach. On this followed immediately the secretion of pepsin and the commencement of digestion proper.[1]

These views and experiments of Schiff have not been allowed to pass without challenge, but they have not yet been overturned. If they should be substantiated they will give, curiously enough, a scientific sanction to the prevailing custom of commencing dinner with soup.

---

[1] See *Leçons sur la Physiologie de la Digestion*, Paris, 1867, t. ii., p. 200 *et seq.*, where the experimental evidence on which he relies is set forth at length.

THE MILK-CURDLING FERMENT—RENNIN.[1]

You all know that one of the most striking properties of gastric juice is to curdle milk. This property is utilised on a large scale in the industrial art of making cheese. Rennet, which has been used for that purpose from remote antiquity,[2] is simply an infusion of the fourth stomach of the calf in brine. The curdling of casein by rennet does not depend upon the acid of the gastric juice, for it takes place when the milk is neutral or even faintly alkaline. It has until lately been believed that this property was an inherent attribute of pepsin, but this opinion is no longer tenable. Brücke succeeded, by a process I need not particularise, in producing pepsin, which had an energetic action on proteids, but which did not possess, except in the feeblest degree, the power of curdling milk. Mr. Benger also found that an extract of pig's stomach in saturated brine, while it possessed energetic action as a milk-curdler, had comparatively only feeble proteolytic powers. We must, therefore, regard the agent in gastric juice which curdles milk as a distinct substance from pepsin.

In the course of my experiments on pancreatic extract I made the unexpected observation that the pancreas also contained an agent capable of curdling milk. I found this property in the pancreas of the pig, the sheep, the calf, the ox, and the fowl. In whatever way the extract of the gland was made, whatever solvent was used, this property of curdling milk was present in it; but the brine extract exceeded all others in curdling capacity. If a few drops of extract of pancreas be added to some warm milk in a test-tube, the milk becomes a solid coagulum in a few minutes. Some minutes later the whey begins to separate from the curd. In short, the action resembles exactly that of calf's rennet; and, so far as I know, you could make cheese with pancreatic rennet as perfectly as you can with gastric rennet. There is, however, not an absolute identity of the two agents. I said just now that gastric rennet produced curdling in neutral and even in faintly alkaline milk; but if the alkali exceed a very small proportion, ordinary rennet does not curdle milk. I found that an alkalescence exceeding that produced by one grain of bicarbonate of soda to an ounce of milk altogether prevented the milk being curdled by gastric rennet. But this is not so with pancreatic rennet. You may add two, three, or four grains of bicarbonate of soda to each ounce of milk, and still the pancreatic rennet will induce curdling with undiminished energy. Milk is likewise curdled by pancreatic extract when quite neutral, and even when very faintly acid. Indeed, it appeared to me that a very faintly acid milk curdled more actively with pancreatic extract than neutral milk, but not so actively as alkaline milk.

---

[1] The name 'Rennin' for the milk-clotting ferment has been proposed by A. S. Lea and W. L. Dickinson. *Journ. of Physiology*, 1890, p. 307.

[2] Cheese was in use among the ancient Hebrews. When Jesse sent David to visit his brethren in the camp of Saul, and to bring them corn and bread, he also instructed him to 'carry these ten cheeses unto the captain of their thousand.'—1 Sam. xvii. 18.

That the curdling agent of the stomach and pancreas is a true ferment, and not some inorganic chemical agent, seems to be proved by the fact that boiling or even heating to 160° F. (70° C.) instantly destroys its power. I found, moreover, that, like other soluble ferments, it is precipitated, but not truly coagulated, by alcohol—for it recovers its solubility and activity when the alcohol is removed, even after a contact of several weeks.

The curdling ferment of the pancreas is a distinct body from trypsin, as the following experiments show. (1) Some brine extract of pancreas (which was known to possess strong proteolytic energy) was acidulated with hydrochloric acid in the proportion of 1 per 1,000, and then placed in the warm chamber at a temperature of 104° F. (40° C.) for a period of three hours. It was then carefully neutralised with bicarbonate of soda. When thus treated the extract was found to have lost its proteolytic power, but its curdling action on milk was almost as energetic as ever. (2) A portion of the same brine extract of pancreas was filtered under vacuum pressure through porous earthenware. The filtered product was found to possess an undiminished faculty of curdling milk, but it had almost no power of dissolving the curds. The curdling ferment had evidently traversed the earthenware freely, but only traces of trypsin had passed through.

What is the real function of the curdling ferment? Seeing its striking reaction with milk, one's first idea is that it must have something to do with the digestion of casein. But a little consideration shows that this idea is altogether improbable. Although all mammalia start life on a milk diet, milk does not form a part of the normal diet of any adult creature except man. Nor can its universal presence in the mammalian digestive organs be regarded as a vestigial phenomenon—a 'memory' of the suckling phase of their existence—for the same curdling property is found in the stomach and pancreas of the fowl, which never at any period of its life fed on milk. Moreover, it may be doubted whether the ferment in question is the actual agent which curdles milk on its passage into the stomach—for the acid of the gastric juice, which also curdles milk, would probably be beforehand with it, inasmuch as its action is a good deal more prompt than that of the ferment. In the pancreatic digestion of milk the occurrence of curdling has appeared to me to be a distinct hindrance to the process. Has this ferment any true digestive functions? I think this is quite open to doubt. Its action on milk is apparently akin to that of the fibrin-ferment on blood—and it may likewise have some kindred purpose—but what that purpose may be I am unable to conjecture.

EMULSIVE FERMENT—DIGESTION OF FATS.

The digestive change undergone by fatty matters in the small intestine consists mainly in their reduction into a state of emulsion, or division into infinitely minute particles. In addition to this purely physical change a small portion undergoes a chemical change, whereby the glycerine and fatty acids are dissociated. The fatty acids thus liberated then combine with the alkaline bases of the bile and pancreatic juice, and form soaps. The main or principal change is undoubtedly an emulsifying process, and nearly all the fat taken up by the lacteals is simply in a state of emulsion, and not of saponification. It is, however, quite certain that both these processes do take place in the small intestine, though in very unequal degrees. The only question in connection with the digestion of fat which I propose to examine is:—Whether these changes are produced by the operation of a soluble ferment or by some other and different agencies. In his latest utterances on this subject Bernard[1] insisted that the digestion of fat, like the digestion of starch and proteids, consisted in the action of a soluble ferment, which he named *Ferment Emulsif.* This ferment, he alleged, first emulsified and then saponified fats. In the intestine the change scarcely went beyond emulsion—in this condition fat was found in the contents of the lacteals. Saponification took place almost exclusively further on, and later in the blood. It is certainly established that the pancreatic juice exercises a marked influence on the digestion of fats, and it is in the pancreas, according to Bernard, that the emulsive ferment is to be found. Bernard demonstrated that healthy pancreatic juice has quite a special faculty of emulsifying fats. Pancreatic tissue has also the same property. If a portion of fresh pancreas be rubbed up with fatty matter and water, you get an emulsion which is quite persistent. I have not had an opportunity of examining the behaviour of pancreatic juice with fatty matter, and cannot therefore speak of its properties; but it is singular—if, as alleged, the effect of pancreatic juice and pancreatic tissue on fat be due to the presence of a soluble ferment—that the extracts of pancreas possess none of the same power. I have made extracts of pancreas in various ways—with simple water, with chloroform-water, with dilute spirit, with solutions of boracic acid, of borax, and of both combined, with glycerine and water, with brine, and with solution of salicylic acid, and of salicylate of soda; and yet I could not satisfy myself that any of these extracts possessed any special power of emulsifying fats nor of liberating the fatty acids and inducing saponification. Paschutin[1] states that the emulsive ferment of the pancreas can be extracted by a solution of bicarbonate of soda. An extract of pancreas made by myself with a two per cent. solution of bicarbonate of soda was indeed found to have a very marked emulsifying power, but it had the same power, even in an enhanced degree, after being boiled, which showed that its emulsifying properties could not depend on the presence of a soluble ferment.

---

[1] Claude Bernard, *Leçons sur les Phénomènes de la Vie*, t. ii., p. 346. Paris, 1879.

---

[1] Hoppe-Seyler, *Physiologische Chemie*, p. 257. Berlin, 1878.

I was equally unsuccessful in my attempts to verify the alleged power of extracts of pancreas, and of crushed pancreatic tissue, to liberate the fatty acids. When fresh pancreas, finely triturated with sand, was digested with milk in the warm chamber, I could not obtain satisfactory evidence of the development of free acid from the decomposition of the fat of the milk by a soluble ferment. The pancreas itself yields a slightly acid solution when infused in water, and a mixture of milk and pancreatic tissue always showed a slight acid reaction; but when this primary acidity was neutralised, no further production of acid took place until such a time had elapsed as was sufficient to permit the development of organised ferments and the origination of the lactic fermentation. If the development of organised ferments was prevented by the addition of antiseptics—such as chloroform or a combination of boracic acid and borax—a mixture of milk and crushed pancreas remained neutral for several days. The same results followed when I operated on emulsions made with crushed pancreas and lard or olive oil. In my numerous observations on the digestion of milk with various pancreatic extracts, I never could detect the production of an acid reaction, unless organised ferments were permitted to intervene.

I obtained similar negative results with almond emulsion. Bernard attributed the formation of an emulsion when almonds (or other oily seeds) were rubbed up with water to the presence in the seeds of a soluble ferment. But I found, to my surprise, that almonds which had been boiled for seven hours still produced a perfect emulsion. As all known soluble ferments are destroyed by boiling, this result seems irreconcilable with Bernard's view. I also found that almond emulsion kept in the warm chamber for six or eight hours at a temperature of 100° F. (38° C.) showed not the slightest evidence of an increase of its original faintly acid reaction. It appeared to be more probable that the fatty matter in the almond existed in the seed in the condition of a solid emulsion, and that the formation of a fluid emulsion by trituration with water was due simply to the liberation of the minutely divided oil particles rather than to the intervention of a soluble ferment.

It is with considerable hesitation that I venture to place myself even in apparent contradiction with so great an observer as was Claude Bernard; and I by no means pretend that these observations traverse the main conclusions for which he contended as to the digestive transformations of fat in plants and animals. The views which Bernard developed on the digestive process are based on inductions so wide, and observations so multiplied, that I feel satisfied that their substantial accuracy will be ultimately established in regard to fat, as they have already been established in regard to starch and cane-sugar.

Some observations made by Brücke promise to throw a fresh light on the digestion of fat. Brücke found that oils and fats which contained an admixture of free fatty acids—in other words, which were more or less rancid—were emulsified by a slight agitation with a weak solution of carbonate of soda. J. Gad extended these observations, and showed that even simple contact of a rancid oil with the alkaline solution was sufficient to effect a mechanical division of the oily matter. I have repeated these observations, and the results are certainly remarkable.

The different behaviour of two specimens of the same oil, one perfectly neutral and the other containing a little free fatty acid, is exceedingly striking. I have here before me two specimens of cod-liver oil—one of them is a fine and pure pale oil, such as is usually dispensed by the better class of chemists; the other is the brown oil sent out under the name of De Jongh. I put a few drops of each of these into these two beakers, and pour on them some of this solution, which contains two per cent. of bicarbonate of soda. The pale oil, you see, is not in the least emulsified; it rises to the top of the water in large clear globules; the brown oil, on the contrary, yields at once a milky emulsion. The pale oil is a neutral oil, and yields no acid to water when agitated with it—in other words, it is quite free from rancidity; but the brown oil, when treated in the same way, causes the water with which it is shaken to redden litmus paper. I was surprised to find that olive oil (salad oil), which appeared quite sweet, and had not the slightest taste or smell of rancidity, gave a milky emulsion with the soda solution. This oil did not yield any acid reaction to water when agitated therewith. Nevertheless it evidently contained a little free fatty acid (probably oleic acid, which is insoluble in water, and therefore does not acidify water shaken up with it), for when a portion of this oil was washed with a strong solution of carbonate of soda, and then allowed to separate, the oil thus freed from acid no longer gave an emulsion with the weak soda solution. It would appear that an admixture of only a very small proportion of free fatty acid is sufficient to induce emulsification—a quantity so small as not to cause any appreciable rancidity to the senses of smell or taste. This specimen of almond oil is to all appearance perfectly sweet, but it communicates a rather sharp acid reaction to water shaken up with it, and it gives, as you see, an instantaneous and perfect emulsion with the soda solution.

The bearing of these observations on the digestion of fat is plain. When the contents of the stomach pass the pylorus they encounter the bile and pancreatic juice, which are alkaline, from the presence in them of carbonate of soda. So that the fatty ingredients of the chyme, if they only contain a small admixture of free fatty acids, are at once placed in favourable circumstances for the production of an emulsion without the help of any soluble ferment, the mere agitation of the contents of the bowel by the peristaltic action being sufficient to effect the purpose.

This view of the matter renders it necessary that fresh inquiries should be made into the effect of gastric digestion on fats. It has hitherto been supposed that fatty and oily substances undergo no change in the stomach, but it is quite possible that something may have been overlooked. It was noted by Richet in the patient with a gastric fistula that the fatty matters were detained a long time in the stomach, and that they only passed through the pylorus with the last portions of the meal. It is also a familiar experience to most dyspeptics that rancid eructations are a frequent occurrence in the later stages of gastric digestion. If it should turn out that among the complex operations taking place in the stomach there occurred some slight decomposition of the neutral fats, and a liberation of a small quantity of free fatty acid, such a result would supply the necessary condition for the emulsification of the neutral fats in the duodenum. In speculating on this subject it is difficult to shut one's eye to the possibility of the intervention of formed or organised ferments in the digestive process. It is well known that fatty acids are liberated in the decomposition of neutral fats by bacteroid ferments (zymophytes), and the presence of ferments of this class in the living stomach has been so repeatedly observed that it may well give rise to the suspicion that they are a normal ingredient of the gastric mucus, and have a normal function to perform in the digestion of some portions of our food. It is not, however, desirable to push speculations of this kind in advance of observed facts, and I only mention them as hints for further inquiry in regard to the digestion of fat.

III.

ON THE ESTIMATION OF THE AMYLOLYTIC AND PROTEOLYTIC ACTIVITY OF PANCREATIC EXTRACTS.

(*From the Proceedings of the Royal Society for* 1881.)

SUMMARY :—Preliminary observations—*Diastasimetry*—Standard starch mucilage—Effect of quantity and time—Effect of temperature—Mode of proceeding—Mode of calculating and expressing the diastasic value—Diastasic value of the pancreas of the pig, ox, and sheep—*Trypsimetry*—Metacasein reaction—Effect of quantity and time—Effect of temperature—Mode of proceeding—Mode of calculating and expressing the tryptic value—Comparison of the enzymic values of the pancreas of the pig, ox, and sheep.

THE degree of activity possessed by preparations of the soluble ferments cannot be ascertained by direct weighing and measuring. The agents to which they owe their power have in no case been obtained in a state of isolation and purity. These agents are known to be indissolubly united with some form of albuminoid matter, and we are constrained to speak of them as if they really were albuminoid bodies. But their mode of action suggests an affinity with the imponderable forces, and points to the conclusion that the relation which these agents bear to their organic substratum is analogous, or at least comparable, to the relation subsisting between a mass of protoplasm and the vital endowments with which it stands possessed.

The activity of preparations of the soluble ferments can only be gauged by their capacity for work. But inasmuch as there is in them no power of growth and multiplication, the amount of energy with which they are endowed is strictly limited,[1] so that when the capacity for work existing in a given liquid or solid preparation of one of these ferments has been ascertained, and has been put into due expression, the amount of energy in a certain quantity of the preparation can be counted in grams or cubic centimeters like that of any other chemical agent.

The term *ferment* has, up to this time, been applied in common to two groups of agents, which, although nearly allied both in their origin and in their mode of action, belong to essentially distinct categories. The organised or formed ferments, of which yeast is the type, are independent organisms with powers of growth and reproduction; and the transformations which constitute their special characteristics as ferments are inseparably associated with the nutritive operations of these organisms. The ferment-power cannot be separated from the ferment-organism by any method of filtration, nor by any solvent. The soluble ferments, on the other hand, pass freely into solution in water—their action is dissociated from the life of the gland-cells which produced them—and they are wholly devoid of the power of growth and reproduction.

Kühne has proposed to distinguish the group of soluble ferments by the name of 'enzyms.' I would suggest the desirability of adopting this term into English, with a slight change of orthography, as 'enzymes,' and also of coining from this root the cognate words which are requisite for clear and concise description. The action of an enzyme may be designated *enzymosis*, and the nature of the action may be spoken of as *enzymic*.

---

[1] For proof of this *see* p. 31 *et seq.*

In the present paper I shall venture to employ these terms in the sense here indicated.

The pancreas is known to be the source of two ferments or enzymes, of capital importance in the digestion of food, namely, an amylolytic enzyme, *pancreatic diastase*, and a proteolytic enzyme, *trypsin*. It is also known that the pancreas takes an important share in the digestion of fats, but it is doubtful whether its power in this respect is due to an enzyme or to an agency of a different character. The present paper concerns itself solely with the amylolytic and the proteolytic functions of the pancreas.

ESTIMATION OF THE AMYLOLYTIC ACTIVITY OF PANCREATIC EXTRACTS—DIASTASIMETRY.

Probably the most accurate mode of estimating the activity of a diastasic solution is to ascertain the amount of sugar produced when a given quantity of the solution is made to act on a given volume of a standard starch mucilage, for a fixed time and at a fixed temperature. This method has already been recognised by Mr. H. T. Brown and Mr. J. Heron in their paper on the transformation of starch by malt infusions.[1] Kjeldahl has developed this method to a further point, and has used it to measure the comparative activity of malt infusions and of saliva.[2]

In the method about to be described a simpler and speedier proceeding was employed, and the results were so brought out as to indicate absolute as well as comparative values. In principle the method consists in ascertaining the quantity of starch mucilage of known strength which can be transformed, by a unit measure of a diastasic solution, to the point at which it ceases to give a colour reaction with iodine, in a unit of time, and at a fixed temperature.

---

[1] *Journal of the Chemical Society*, September, 1879.

[2] *Compte Rendu des Travaux du Laboratoire de Carlsberg*, 1879, p. 129.

When starch mucilage is treated with extract of pancreas, or with any other diastasic solution, the mixture progressively loses its property of giving a colour reaction with iodine. First the blue reaction of unaltered starch passes away, then the brown and yellow reactions of dextrine successively disappear. It is not difficult to fix, with a fair amount of accuracy, the vanishing point of this reaction. This point may, for our present purpose, be called the *achromic point*.

The extract of pancreas employed in these observations was prepared by digesting fresh pancreas, freed from fat and chopped up, in four times its weight of dilute alcohol, containing 25 per cent. of rectified spirit (sp. gr. 0·838). The digestion was continued for four or five days, with occasional agitation. The mixture was then filtered through paper. Filtration is much facilitated by the addition to the solvent of 0·02 per cent. of acetic acid (containing 28 per cent. dry acetic acid).

The *standard starch mucilage* was made from potato starch. Owing to the large size of its granules, potato starch is easily obtained in a state of great purity, by repeated levigation with water, and afterwards drying the product at 40° C.[1] The mucilage was made of the strength of 1 per cent., and in the following manner: 5 grams of starch were well stirred up into a thin mud with 30 cubic centimeters of water, and then poured in a slender stream into 470 cubic centimeters of briskly boiling water. The mixture was stirred and allowed to boil for a few seconds. Thus prepared, the mucilage is perfectly smooth and uniform, and is so diffluent that it can be measured out like an ordinary liquid. This is known in the present paper as the *standard starch mucilage*. It should be used fresh, for it is apt to change in a few days, and to lose its opalescent appearance and slight mucilaginous consistency. When thus changed it is found to contain sugar. So long as it maintains its slight opalescence and slight mucilaginous character it is fit for use.

---

[1] The so-called pure starch of the shops is worthless for the purposes of diastasimetry. A supply of pure potato starch may be obtained from Mottershead & Co., chemists, Manchester.

The *iodine solution* used in the testing was composed of 1 part of the liquor iodi of the British Pharmacopœia diluted with 200 parts of water.

In determining the data on which is based the method of diastasimetry here proposed, it was necessary to ascertain the mutual relations in regard to the amylolytic process of three factors—namely, the *quantity* of pancreatic extract set in action, the *time* required to reach the achromic point, and the *temperature* at which the enzymosis was carried on.

Quantity and Time.—The amount of amylolytic work done by a given sample of pancreatic extract is strictly proportional to the quantity of it set in action—in other words, the amount of the standard starch mucilage which can be changed to the achromic point in a given time and at a given temperature *varies directly* as the quantity of the extract employed. This law of proportionality may probably be regarded as fundamentally applicable to the action of all enzymes, which, having no power of growth or multiplication, conform in this respect to the common law which governs the action of ordinary chemical agents. The rule is, however, liable to interference if the products of the enzymosis accumulate in the solution to such a degree as to hamper the action. In the conditions observed in the following experiments this interference did not arise. The starch mucilage operated on was exceedingly dilute, and consequently the sugar and dextrines produced in the transformation never accumulated to such a degree as to check the enzymosis.

In the action of all enzymes the element of time is an essentially important factor. An enzyme liberates its energy gradually, in successive portions, and it takes a comparatively long time to exhaust itself completely. I found that pancreatic diastase, in the presence of excess of starch mucilage, took not less than forty-eight hours to completely exhaust itself at the temperature of 40° C. (*see* p. 33).

The fundamental rule which governs the mutual relations of quantity and time in the action of an enzyme is that of *inverse proportion*. That is to say, double the quantity of an enzyme will do a given amount of work in half the time, and that half the quantity will require double the time. This rule, however, is apparently controlled by another rule, namely, that *an enzyme liberates its energy at a progressively retarded rate*. If we conceive an enzyme as a body in a state of tension, charged with a certain amount of dormant energy, we can further conceive that in action it will discharge this energy gradually, and also at a rate which is continually diminishing. Such a conception will, I think, enable us to understand some features in the action of diastase and trypsin which are otherwise difficult to explain.

In regard to the action of pancreatic extract on starch mucilage, the rule of inverse proportion between quantity and time was found to hold good within considerable limits, as the following experiments show :—

Table I.—*Experiments showing the inverse proportion between quantity and time in the action of Pancreatic Extract on Starch Mucilage.*

The quantity of the standard mucilage acted on in each experiment was 10 c.c. diluted with water up to 100 c.c. Temperature 15° C. The 'calculated' time in the third column was obtained by taking the middle observation in each set as a standard of comparison.

—	Quantity of Pancreatic Extract employed	Time in which the Achromic Point was reached	
		Found	Calculated
I. . .	0·02 c.c.	34 minutes	36 minutes
	0·04 „	18 „	18 „
	0·08 „	9 „	9 „
	0·10 „	7 „	7⅕ „
	0·20 „	3 „	3½ „
II. . .	0·4 „	4¾ „	5 „
	0·2 „	10 „	10 „
	0·05 „	40 „	40 „

In both sets of observations the inverse time-rate is seen to come out true with almost mathematical accuracy.

When, however, a relatively small quantity of pancreatic extract was employed, and the time required to reach the achromic point was, in consequence, considerably lengthened, it was found that the advent of the achromic point was postponed beyond the term indicated by the rule. If the period occupied in reaching the achromic point fell within the compass of an hour, and the temperature was low, as in the observations above recorded, the inverse time-rate came out true, but when the period of action extended to several hours, and the temperature stood higher, the departure from the rule was undoubted. The annexed table gives the results of experiments made with a view of testing this point :—

TABLE II.—*Experiments showing the postponement of the Achromic Point when the action is protracted.*

The quantity of standard mucilage acted on in each case was 10 c.c. diluted with water up to 100 c.c. Temperature 40° C. The 'calculated' time in the third column was obtained by taking the first observation, which was several times repeated, as a standard of comparison.

Quantity of Pancreatic Extract employed	Time in which the Achromic Point was reached	
	Found	Calculated
0·05 c.c.	10 minutes	—
0·005 "	115 "	100 minutes
0·004 "	140 "	125 "
0·002 "	300 "	250 "
0·0005 "	1,380 "	1,000 "

It need scarcely be said that when the enzymosis is very slow it is not possible to fix the vanishing point of the colour reaction with the same precision as when the action is more rapid and the change more abrupt. Notwithstanding this source of error, I think the conclusion indicated by these experiments may be relied on. The postponement of the achromic point shown in the table may be explained, as has been suggested, on the assumption that the enzyme liberates its energy at a continually retarded rate. In the case of trypsin we shall see evidence of a precisely parallel phenomenon.

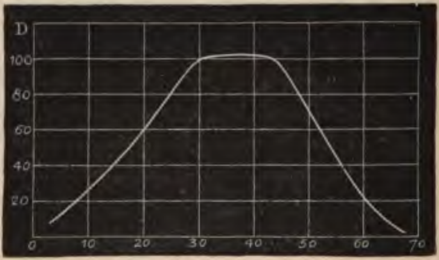
Temperature.—The action of pancreatic diastase on starch mucilage was found to increase in energy (or speed) from zero up to 30° C. From this point to 45° the rate of action continued steady, showing a range or platform of indifferent temperature extending from 30° to 45°. Above 45° the action became less and less energetic, and finally ceased between 65° and 70°. The following table exhibits the results obtained at various temperatures between 5° and 70° C.:—

TABLE III.—*Showing the effects of Temperature on the action of Pancreatic Diastase.*

The amount of the standard mucilage acted on in each experiment was 10 c.c. diluted with water up to 100 c.c. The quantity of pancreatic extract employed in each experiment was 0·1 c.c.

Temperature	Achromic Point reached in
3—5° C.	36 minutes.
10°	18 ,,
15°	12 ,,
20°	8 ,,
25°	6 ,,
30°	5 ,,
40°	5 ,,
45°	5 ,,
50°	7 ,,
55°	10 ,,
60°	40 ,,
65°	Very slow action.
70°	No action.

These results, thrown into the form of a curve, are shown in the subjoined diagram. The ordinates indicate the diastasic value, or D, as calculated by a method to be presently explained; the abscissæ represent the temperatures.



Curve illustrating the effect of temperature on the action of pancreatic diastase.

Mode of Proceeding.—In testing the activity of a sample of pancreatic extract, it was found on the whole more convenient to operate on a fixed quantity of the standard mucilage, and to vary the quantity of extract added to it, than to proceed contrariwise. The bulk of liquid operated on was thus kept constant. The ordinary proceeding was as follows: 10 cubic centimeters of the standard mucilage were mixed in a beaker with 90 cubic centimeters of water. The mixture was then warmed to 40° C., or at least to some point well within the range of indifferent temperature extending from 30° to 45° C. This was done in order to eliminate the disturbing influence of temperature. The next step was to add the determined quantity of the extract to be tested to the diluted mucilage, and to note the exact time. Then, at short intervals, a drop of the enzymosing liquid was placed on a white slab, or plate, with a drop of the iodine solution. The time and result of each testing was noted. When the achromic point was reached the time was marked, and the interval from the commencement of the experiment was computed. If at the end of three minutes the mixture still gave the blue reaction of unaltered starch, a new experiment was made, using two, three, or four times the quantity of extract. If, on the other hand, the achromic point was reached in less than two minutes, a new experiment was made, using a smaller quantity of the extract. Two or three experiments generally sufficed to determine the quantity of extract required to bring the achromic point within a period ranging from two to ten minutes. A final control experiment enabled the operator to fix the achromic point somewhere between four and six minutes. The accuracy of the method depends chiefly on the sharpness and precision with which the occurrence of the achromic point can be determined. If it occur earlier than two minutes, the transition is too rapid for exact observation and record. On the other hand, if it occur later than fifteen or twenty minutes, the transition is too gradual for precise limitation. The most satisfactory results are obtained when the achromic point falls between four and six minutes.

The following example will serve as an illustration of the way in which the experiments were carried out, noted, and expressed:—

TABLE IV.—10 *c.c. standard Starch Mucilage* + 90 *c.c. water* + 0·1 *c.c. Pancreatic Extract—at* 40° *C.*

Time	Reaction with Iodine
10.30 A.M.	Commencement of experiment.
10.31 "	Blue.
10.32 "	Violet.
10.33 "	Brown.
10.34 "	Yellowish-brown.
10.35 "	Pale yellow.
10.36 "	No reaction—achromic point.
6 minutes.	

Achromic point reached in 6 minutes.

The result of the experiment was expressed in the first instance as follows: 0·1 cubic centimeter pancreatic extract + 10 cubic centimeters standard mucilage = 6 minutes at 40° C.

From this somewhat incongruous expression it is, however, easy to extract by a simple formula, in the manner to be now explained, a correct and convenient expression for the diastasic value of any amylolytic solution.

MODE OF CALCULATING AND EXPRESSING THE DIASTASIC VALUE.

The principle of the method consists, as already stated, in ascertaining the amount of starch mucilage of known strength which can be transformed by a unit measure of the diastasic solution to the point at which it ceases to give a colour reaction with iodine, in a unit of time and at a given temperature.

In reducing this principle to a definite formula it was necessary to choose arbitrarily a unit of measure of the diastasic solution and a unit of time. The unit of measure fixed on was 1 cubic centimeter, and the unit of time five minutes. These selections seemed, on the whole, the best adapted for furnishing a convenient scale. On these bases the formula took the following form: the diastasic value of any solution—or, D—is expressed by the number of cubic centimeters of the standard starch mucilage which can be transformed to the achromic point by 1 cubic centimeter of the solution to be tested in a period of five minutes at a given temperature.

In the process of testing, the quantity of the standard mucilage was made constant, namely 10 cubic centimeters, and the quantity of pancreatic extract and the time were made variable. In order to get the value of D the results must be so transformed as to make the quantity of extract and the time constant, and the quantity of the standard mucilage variable. This is accomplished by increasing or reducing the quantity of pancreatic extract employed to 1 cubic centimeter, and increasing or diminishing the standard mucilage in the same proportion. The product thus obtained is again increased or reduced in the same proportion as is requisite to increase or reduce the time found to five minutes. Taking the example above given (Table IV.), the value of D is obtained by the following formula: Let p signify the quantity of pancreatic extract employed, and m the number of minutes found requisite to reach the achromic point, then:—

$$\frac{10}{p} \times \frac{5}{m} = \mathrm{D},$$

and in the above example—

$$D = \frac{10}{0{\cdot}1} \times \frac{5}{6} = 83 \text{ at } 40^\circ \text{ C.}$$

The value of D, as already explained, signifies the number of cubic centimeters of the standard starch mucilage which can be changed to the achromic point by 1 cubic centimeter of the diastasic solution in five minutes at a given temperature. As the standard mucilage contains 1 per cent. of dry starch, the value of D divided by 100 gives us the same value in terms of dry starch, and the result of the above experiment may be read as follows:—

$$D = 83 = 0{\cdot}83 \text{ grm. of dry starch.}$$

This method of diastasimetry is equally applicable to saliva and malt-diastase. It may also be applied to the estimation of the diastasic agent which is present in urine, and presumably to all diastasic solutions. In the case of solid preparations containing diastase—like malt or glandular tissue—a solution in known proportions must first be prepared; and from the ascertained activity of such solution the proportionate activity of the solid substance can be easily calculated. I may here mention some of the results which this method has already yielded.

Pancreatic Tissue.—The pancreatic tissue of the pig (obtained from animals killed for the market in the fasting state) yielded an extract which, when made on the large scale, possessed a mean diastasic value of 100. This extract is sent out by Mr. Benger, of the firm of Mottershead & Co., chemists, Manchester, under the name of 'Liquor Pancreaticus,' and is made in the proportion of one part of pancreatic tissue to four of solvent (water containing 25 per cent. rectified spirit). This value indicates that 1 grm. of the moist pancreas of the pig is capable of transforming 4 grms. of dry starch to the point at which it no longer gives a colour reaction with iodine, in five minutes, at a temperature of 40° C.

The pancreatic tissue of the ox and sheep yielded an extract (made in the same proportions) which was of far inferior activity. The ox extract had a diastasic value of about 11 and that of the sheep of about 12. These numbers indicate that in point of diastasic activity the pancreas of the pig has ten times the value of the pancreas of the ox and sheep. This extraordinary difference is probably linked with the diversity of their food. The pig is fed largely upon potatoes and meal, which are rich in starch; the ox and sheep, on the other hand, feed on grass, which is poor in starch. We shall presently find that there is no such difference in regard to tryptic activity in the pancreas of these animals.

Human Saliva.—Filtered saliva was found to have a diastasic value varying from 10 to 17 at 40° C. Its action was influenced by temperature exactly in the same manner as that of pancreatic extract. Saliva increased in energy up to about 30° C., and continued steady from this point to about 45°; above this point its activity declined, and was finally extinguished between 65° and 70°.

Malt Diastase.—Infusions of malt made in the proportion of one part of crushed malt to four parts of water exhibited a diastasic value of 4 to 5 at 40° C. But malt diastase did not attain its maximum activity at this temperature. It continued to increase in energy up to about 60° C., when it showed a diastasic value of 10. Above 60° the action diminished in energy, but did not come to a full stop until the temperature approached 80° C.

Human Urine.—Several specimens of healthy urine were tested by this method. They showed a diastasic value varying from 0·03 to 0·13 at 40° C. The effect of temperature thereon was not examined.

ESTIMATION OF THE PROTEOLYTIC ACTIVITY OF PANCREATIC EXTRACTS—TRYPSIMETRY.

The writer had found in previous inquiries that when milk is subjected to digestion with pancreatic extract a striking change takes place in it at an early stage of the process—the milk acquires the property of curdling when boiled. The onset of this reaction occurs at an earlier or at a later period according to the activity of the extract and the quantity of it employed; and it is possible to fix the time of its advent with considerable accuracy—sufficient accuracy to serve as the basis of a method of measuring the proteolytic activity of pancreatic extracts.

The reaction in question depends on the production, as a first step in the pancreatic digestion of casein, of a modified form of that body which I have named *metacasein*. This substance resembles casein in being curdled by acetic acid in the cold; but it differs from casein in being also curdled by simple boiling. These two reactions together distinguish metacasein from other proteid bodies.

The property of curdling when boiled, which may be called the *metacasein reaction*, continues observable in milk undergoing tryptic digestion until near the termination of the process; it then disappears somewhat abruptly, and the milk, when boiled, remains fluid just as it did at first.

We may therefore speak of the *onset point* of the metacasein reaction, and of the *vanishing point* of the metacasein reaction. These two points mark respectively the initial and the terminal limits of the principal phase in the digestion of milk by pancreatic extract.

Before the onset point of the reaction—that is, distinct and undoubted curdling on boiling—is actually reached, its approach is indicated by an appearance of soiling of the sides of the test-tube in which the milk has been boiled. This appearance is due to incipient coagulation, which presently develops into pronounced curdling, and is a useful sign in testing to indicate the coming on of the metacasein reaction.

The following typical experiment may serve to give the reader a clear notion of the succession of events—so far as they concern us here—which occur when milk is submitted to digestion with pancreatic extract:—

TABLE V.—4 *c.c. Pancreatic Extract added to* 50 *c.c. Milk diluted with Water to* 100 *c.c. Temperature*, 18° *C.*

Time	Reaction on Boiling
2 minutes . .	No change.
3 " . .	Slight soiling of the sides of the test-tube.
4 " . .	More soiling.
5 " . .	Distinct curdling—*onset point* of the metacasein reaction.
6 " . .	More pronounced curdling.
10 to 80 " . .	Pronounced curdling.
90 " . .	Diminished curdling.
95 " . .	Slight curdling.
100 " . .	No change; *vanishing point* of the metacasein reaction.

The length of time during which the successive steps of the transformation may continue observable depends on the energy of the action; and this, in its turn, depends on the activity of the preparation and the quantity of it added to the milk; it is also greatly influenced by temperature. By using an excess of an active pancreatic extract, and with a favourable temperature, all the steps of the process may be crowded almost into an instant of time; with converse conditions the action may linger on for many hours.

Although milk is a secretion of somewhat variable composition, the oscillations which it exhibits, when it is the product of a dairy, and is not intentionally adulterated, do not materially vitiate it for the purposes of a test fluid such as is here required. The milk delivered at my house presented very little variation. It had a density of 1030—seldom varying more than a degree from this point—and the results obtained with the milk of different days showed a remarkable uniformity. Milk from different dairies, and at different seasons of the year, would no doubt present greater irregularities. Milk should, however, be used fresh, for if it have become slightly acid, as it is apt to do in keeping, the results obtained are untrustworthy.

If milk be diluted with water the occurrence of the metacasein reaction is postponed, and the degree of postponement varies with the degree of dilution. For example, if 50 cubic centimeters of pure milk are changed to the onset point of the metacasein reaction in three minutes, the same quantity of milk diluted with an equal volume of water will take six minutes to reach the same point—other conditions being equal. There are, however, several advantages in using diluted milk instead of pure milk as the experimental fluid. The inequalities of the milk are thereby minimised. The 'strike' of the reaction is more sharply defined, and the required quantity of pancreatic extract can be included in the water of dilution. This last is an important advantage, because if the extract to be tested is feeble a considerable quantity of it requires to be added, and this, if pure milk were employed, would seriously alter the degree of dilution, and thereby vitiate the results. In the following experiments milk diluted with an equal bulk of water was invariably employed; and if the quantity of pancreatic extract to be added exceeded 3 cubic centimeters for every 50 cubic centimeters of milk, this was always included in the water of dilution.

In principle the method of trypsimetry here proposed consists in ascertaining how many cubic centimeters of milk can be changed to the onset point of the metacasein reaction in five minutes by 1 cubic centimeter of the extract to be tested, at a given temperature.

In settling the data on which the method is based it was necessary, as in the case of diastase, to determine the relations of tryptic action to *quantity*, *time*, and *temperature*.

Quantity and Time.—The rule of inverse relations between quantity and time which was found to be valid within a wide range in the case of diastase and starch is only reliable in the case of trypsin and milk within narrow limits. When the time of action exceeds 8 or 10 minutes the advent of the metacasein reaction is postponed beyond the term indicated by the rule of inverse proportion, and this postponement increases as the time of action is lengthened. The following two sets of observations may be taken as samples of the results obtained by experiment in regard to this point.

If the vanishing point of the metacasein reaction was taken as the test of comparison, the results approximated a little more nearly to the requirements of the rule of inverse proportion than when the onset point was taken, especially at low temperatures; but still the evidence in either case pointed in the same direction, and indicated that trypsin, like diastase, exhausts itself in action at a progressively retarded rate.

ture, all the stages of the process may
into an instant of time; with conv
action may linger on for many hours

Although milk is a secretion of
composition, the oscillations which it
the product of a dairy, and is not i
mated, do not materially vitiate it for
test fluid such as is here required.
at my house presented very little v
density of 1030—seldom varying m
from this point—and the results obta
of different days showed a remarkabl
from different dairies, and at differ
year, would no doubt present gre
Milk should, however, be used fresh, f
slightly acid, as it is apt to do in h
obtained are untrustworthy.

If milk be diluted with water
the metacasein reaction is postponed,
postponement varies with the degree
example, if 50 cubic centimeters o
changed to the onset point of the meta
three minutes, the same quantity of
an equal volume of water will take six
the same point—other conditions bei
are, however, several advantages in u
instead of pure milk as the experiment
qualities of the milk are thereby
"strike" of the reaction is more sharply
required quantity of pancreatic extract
in the water of dilution. This last
advantage, because if the extract to be
a considerable quantity of it requires
this, if pure milk were employed, wou

he degree of dilution, and thereby vitiate the results. n the following experiments milk diluted with an equal ulk of water was invariably employed; and if the uantity of pancreatic extract to be added exceeded 3 ubic centimeters for every 50 cubic centimeters of milk, his was always included in the water of dilution.

In principle the method of trypsimetry here proposed consists in ascertaining how many cubic centimeters of milk can be changed to the onset point of the metacasein reaction in five minutes by 1 cubic centimeter of the extract to be tested at a given temperature.

In settling the data on which the method is based it was necessary, as in the case of diastase, to determine the relations of tryptic action to *quantity, time,* and *temperature.*

Quantity and Time.—The rule of inverse relations between quantity and time which was found to be valid within a wide range in the case of diastase and starch is only reliable in the case of trypsin and milk within narrow limits. When the time of action exceeds 5 or 10 minutes the advent of the metacasein reaction is postponed beyond the term indicated by the rule of inverse proportion, and this postponement increases as the time of action is lengthened. The following two sets of observations may be taken as samples of the results obtained by experiment in regard to this point.

If the vanishing point of the [illegible] taken as the test of comparison [illegible] mated a little more nearly to the [illegible] rule of inverse proportion than [illegible] was taken, especially at low [illegible] the evidence in either case [illegible] tion, and indicated that trypsin [illegible] itself in action at a progressively [illegible]

TABLE VI.—*Showing undue postponement of the Metacasein Reaction when the Enzymosis is slow.*

The quantity of milk acted on in each experiment was 50 c.c. diluted with water up to 100 c.c. The 'calculated' time in the third column was obtained by taking the first observation in each set as the standard of comparison.

Quantity of Pancreatic Extract added	Onset Point of the Metacasein Reaction	
	Found	Calculated
	Set I.—Temperature 40° C.	
1·0 c.c.	3 minutes	—
0·8 ,,	4 ,,	3¾ minutes
0·6 ,,	5 ,,	5 ,,
0·4 ,,	9 ,,	7½ ,,
0·2 ,,	30 ,,	15 ,,
	Set II.—Temperature 16° C.	
4·0 c.c.	6 minutes	—
2·0 ,,	16 ,,	12 minutes
1·0 ,,	39 ,,	24 ,,
0·5 ,,	105 ,,	48 ,,
0·25 ,,	280 ,,	96 ,,

From the numerous experiments which were performed with a view of elucidating this point I arrived at the conclusion that when the onset point of the metacasein reaction fell between 3 and 6 minutes the inverse time-rate gave a reliable basis of calculation, but not beyond these limits.

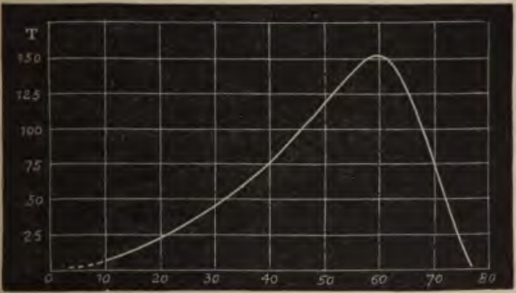
Temperature.—Tryptic enzymosis is exceedingly sensitive to temperature. The action of trypsin on milk increases in energy from zero to 60° C. Above this point there is a rapid fall, and the action is finally arrested between 75° and 80° C. There is not, as with diastase, any range or platform of indifferent temperature. The following table exhibits the degrees of activity from 10° to 80°. In order to obtain the utmost uniformity of results, the quantities of pancreatic extract employed were so adjusted as to bring the time of the occurrence of the metacasein reaction within a period ranging from 4 to 6 minutes :—

TABLE VII.—*Showing the effects of Temperature on Tryptic Enzymosis.*

The quantity of milk employed in each experiment was 50 c.c. diluted with water up to 100 c.c. In the fourth column the degree of tryptic activity, or T, was calculated by a method to be presently explained.

Temperature	Quantity of Pancreatic Extract employed	Onset point of the Metacasein Reaction	Tryptic Value—or T
10° C.	6·0 c.c.	5 minutes	8
15°	4·0 "	5 "	12
20°	3·0 "	4 "	21
30°	1·0 "	5½ "	45
40°	0·6 "	5½ "	76
50°	0·4 "	5¼ "	119
60°	0·3 "	5½ "	150
65°	0·4 "	5 "	125
70°	0·8 "	4 "	78
75°	2·0 "	6 "	21
80°	4·0 "	No action	0

In the subjoined diagram these results are thrown into the form of a curve. The ordinates indicate the



Curve illustrating the effect of temperature on the tryptic digestion of milk.

degrees of tryptic activity (or, T), and the abscissæ indicate the temperatures.

In another series of experiments the effect of temperature was gauged by the length of time required to reach the onset or the vanishing point of the metacasein reaction when constant quantities of pancreatic extract were used. The results obtained in this series are tabulated in Table VIII. In the first set the onset point of the reaction was taken as the index of tryptic activity; in the second set the vanishing point of the reaction was employed for the same purpose. The results brought out by these experiments correspond pretty closely with those given in Table VII.

TABLE VIII.—*Showing the effect of Temperature by the length of time required to reach the Metacasein Reaction, when constant quantities of Pancreatic Extract are used.*

I. Set. 0·4 c.c. Pancreatic Extract with 100 c.c. Diluted Milk		II. Set. 4 c.c. of Pancreatic Extract with 100 c.c. Diluted Milk	
Temperature	Onset Point of the Metacasein Reaction	Temperature	Vanishing Point of the Metacasein Reaction
2 to 5° C.	312 minutes	—	—
10°	168 "	10° C.	180 minutes
15°	120 "	—	—
20°	70 "	20°	75 "
30°	25 "	30°	26 "
40°	12 "	40°	12 "
50°	6 "	50°	6 "
60°	4 "	60°	4 "
65°	6 "		
70°	action suspended, but resumed on cooling		

An examination of the table shows how very nearly the results correspond, whether the onset point or the vanishing point of the metacasein reaction be taken as a measure of tryptic activity. This correspondence substantiates the conclusion that the onset point of the reaction furnishes a trustworthy index of the activity of tryptic digestion. The proportionate quantity of pancreatic extract added to the milk in the experiments recorded in Set II. of Table VIII. was ten times as great as in those recorded in Set I.; and it is seen that, by using these proportions, the vanishing points and the onset points fell out in nearly the same times in both sets of experiments.

Mode of Proceeding.—In testing the tryptic activity of a sample of pancreatic extract the following procedure was adopted:—50 cubic centimeters of fresh milk were diluted with 50 cubic centimeters of water, less the quantity of extract intended to be added. The diluted milk was then warmed to 40° C., and maintained exactly at that temperature until the close of the experiment. The intended quantity of the pancreatic extract, say 1 cubic centimeter, was then added, and the time exactly noted. At the end of each minute a portion of the digesting milk was withdrawn, and boiled for a few seconds in a test-tube, inclining the test-tube to one side after the boiling in order to observe the effect. The result was at once noted down. As soon as distinct curdling occurred on boiling, the experiment was considered finished; the time was recorded, and the number of minutes which had elapsed from the commencement of the experiment were reckoned. The result came out in the following form:—

1 c.c. panc. extract + 50 c.c. milk = 4 minutes at 40° C.

If no signs of incipient curdling (soiling of the sides of the test-tube) occurred within 3 minutes a new experiment was made, using two, three, or four times as much pancreatic extract. If, on the other hand, distinct curdling occurred in 2 minutes or less, a fresh experiment was made, using half or quarter the quantity of extract. Three or four such experiments usually sufficed to enable the operator to fix the onset point of the reaction somewhere between 4 and 6 minutes.

Mode of Calculating and Expressing the Tryptic Value.—The object of the experiment was to ascertain how many c.c. of milk can be changed to the onset point of the metacasein reaction by 1 c.c. of extract in a period of 5 minutes at the temperature of 40° C. The tryptic value, or T, was calculated from this first expression of the results of an experiment in exactly the same way as for diastase. If p be made to signify the quantity of pancreatic extract added to the milk, and m the number of minutes which were required to reach the onset point of the metacasein reaction, then the value of T was obtained by the following formula :—

$$\frac{50}{p} \times \frac{5}{m} = \text{T},$$

and taking the experiment above given the value of T came out as follows :—

$$\text{T} = \frac{50}{1} \times \frac{5}{4} = 62{\cdot}5 \text{ at } 40^\circ \text{ C.}$$

In judging the practical value of this method of trypsimetry one must have regard to the inherent difficulty of estimating the activity of preparations of the proteolytic enzymes. I venture to think that we have in this method a means of estimating the activity of trypsin preparations which is superior in ease and precision to any we possess for the evaluation of pepsin preparations. What may be the limits of error arising from inequalities in the composition of milk I am unable to say, but with the same specimen of milk the limits of error do not certainly exceed 6 to 8 per cent.

The tryptic value of pancreatic extract from the pig, made on the large scale, was found to range from 40 to 70 at 40° C. The pancreatic tissue of the ox and sheep yielded an extract which possessed about the same tryptic activity as that of the pig. Extracts prepared from single glands presented very considerable variations both in regard to their diastasic and their tryptic activity. The following table shows the enzymic values of twelve samples of pancreatic extract prepared with single glands from four pigs, four oxen, and four sheep, killed for the market :—

Table IX.

All the observations were made at 40° C. D stands for diastasic value, and T for tryptic value.

Pig		Ox		Sheep	
No. 1	D=166 T=64	No. 5	D=8 T=64	No. 9	D=5 T=125
No. 2	D=100 T=83	No. 6	D=10 T=50	No. 10	D=12 T=83
No. 3	D=100 T=72	No. 7	D=9 T=42	No. 11	D=14 T=64
No. 4	D=100 T=64	No. 8	D=13 T=83	No. 12	D=4 T=28

It may be observed that the oscillations in the two enzymic values bear no mutual relations to one another.

The most appropriate standard of temperature for the valuation of tryptic activity is 40° C., because this corresponds very nearly with the temperature at which trypsin operates in the normal digestion of warm-blooded animals. But it is more convenient to perform the testing at, or near, the ordinary temperature of the room (say at 20°), inasmuch as in the latter case it is much less troublesome to maintain a continuously uniform temperature than at 40°.

I have therefore taken some pains to ascertain the exact relation between the value of T at 40° and at 20° respectively, and have found that at 40° the value of T is very nearly three and a half times as great as at 20°. If, therefore, the testing be performed at 20°, the resulting value of T multiplied by 3·5 will give with sufficient accuracy the value of T at 40°.

SECTION II

DIETETICS

I.

INTRODUCTORY—ON DIETETICS IN GENERAL.

(*First Lecture of the Owens College Course.*)

SUMMARY:—Dyspeptic troubles more common in man than animals—Causes of this—Complexities of the human dietary—Science of dietetics based on observation of food-customs—Food-customs of leading races—Use of meat—Alcoholic beverages—Tea, coffee, and cocoa—Dietetic habits of the two sexes—Secondary dietetic habits for the young and for the aged—Effect of the quality of the food on nutrition and vital habits—High feeding and low feeding—Comparison of characteristics of high-fed and low-fed classes and races—Calculating the man-value—Connection of mental capacity with nutrition.

DEFECTS and derangements of digestion are among the most common of human ailments. They not only complicate almost every variety of disease, but they constitute by themselves a serious torment to a large number of otherwise healthy people. Not a few of those who bear a large and vigorous part in the world's work, and mayhap reach a green old age, are plagued half their days with dyspeptic troubles. These unfortunates have no sooner reached the full adult state, and have ceased to grow and gather weight, than they enter on a period of gastric discord in which there seems to be a permanent want of due adjustment between their digestive functions and their food supplies. Besides these habitual dyspeptics there are also a multitude of others, also healthy, who are liable to frequent paroxysms or fits of indigestion. Any unusual worry or anxiety, or any trifling irregularity in the quantity, quality, or order of their meals, disturbs the tranquillity of their digestive processes.

The digestion of food is, as you know, at bottom perhaps the most simple of all our functions: it can be imitated with remarkable precision in a glass vessel in a laboratory experiment. The articles of our food consist, fundamentally, of a few common alimentary principles, which can be counted on the five fingers—proteid substances, collagenous matters, starchy and saccharine compounds, and fat. Both in regard to his digestive juices and the alimentary principles submitted to their operation, man does not differ in any essential particular from the lower animals, and yet it would seem as if the function of digestion were less perfectly adjusted, and its equilibrium more easily disturbed in man than in the lower animals. The cause of this discrepancy is to be sought partly in the quicker and more universal sympathies of his nervous system, and partly and chiefly in the extraordinary complexities which civilised man has introduced into his dietary. He has departed widely, and is departing more and more, in regard to his food, from the simplicity and uniformity of his primitive nature. Scarcely any two of his meals are exactly alike[1]—and although the adjustive power of his digestive organs keeps pace in the main with this increasing complexity, the process of adjustment in many individuals seems to lag a good deal behind their requirements.

---

[1] This variability or diversity is a marked characteristic of the diet of the civilised races. Not only do the several daily meals—breakfast, dinner, &c.—differ from each other, but among the easier classes the breakfast or dinner of one day generally differs more or less from the corresponding meal of another day. Animals in a state of nature exhibit little or none of this diversity—their diet is generally wholly monotonous.

The first class of complications with which our digestive organs have to deal are those arising from the elaborate preliminary preparations, and especially the numerous cooking processes, to which our food is subjected. In regard to a large part of our food the process of cooking is an absolute necessity; we have no power of digesting farinaceous articles without previous cooking, and the same may be said of the collagenous tissues of animal flesh. But although we speak of cooking as if it were a definite change impressed on articles of food by means of heat, the degree of cooking differs greatly. We boil or roast animal flesh to varied degrees, and in the preparation of cereal articles there is very great difference in the degree of cooking. A well-boiled gruel may be said to be fully cooked, and well-baked bread may be said to be highly cooked, but pastry is usually very imperfectly cooked. The complexity thus introduced obviously renders the task of adjustment in our digestive organs more difficult than if our diet were of a more uniform character. Again, we use a number of condiments with our food to which the lower animals are strangers—salt, vinegar, curries, spices, and sauces of all sorts.

But by far the most remarkable departure on the part of man in regard to his food from the common ways of the animal world is the practice he has acquired of using in large quantities certain articles of a stimulant or restorative character, of which the chief are alcoholic beverages and tea and coffee. These articles are not themselves endowed with nutrient properties; but inasmuch as they are taken with food, and mingle therewith in the digestive passages, they directly complicate the task of the digestive organs, as we shall see further on.

There are, therefore, in the study of human digestion problems of great interest and importance which we do not encounter at all in the study of the digestion of the lower animals; and I propose, in the course of these lectures, to examine in some detail the effects of alcoholic beverages, and of tea and coffee, and of one or two condiments, on the processes of digestion.

But before coming to this subject I have some observations to make, of a somewhat fragmentary character, having reference to dietetics in general.

The science of dietetics must, I apprehend, be mainly based and built up on an observation and a study of the practices and customs of mankind in regard to their food rather than upon any *à priori* data supplied by physiology. In the case of the lower animals, we assume that each creature selects from the nutrient materials within its reach those articles which are most suited to its well being and are best fitted to promote its success in the struggle for existence, and that it is guided in this selection by an almost unerring instinct. This, like other instincts, in now explained by biologists as consisting essentially in an inherited experience, which has been gradually accumulated through a long line of ancestors, and is transmitted by heredity to the descendants.[1] Accordingly, when we see an animal feeding on a particular kind of food we conclude without hesitation that that food is, of all the nutrient materials accessible to it, the best adapted for the special wants of its economy. But we know that man, in regard to his bodily functions, is subject to the same laws as those which govern the life of the lower animals. And we cannot doubt that in the formation of his dietetic habits man is guided by the same kind of instincts as those which guide the rest of the animal creation in the choice of their food.

---

[1] In agreement with this explanation, it is found that when animals are placed under circumstances which are new to them, and which are beyond the teaching of any possible ancestral experience, their food-instincts fail them. Thus vermin can be easily poisoned by the artificial mixture of poisonous substances with their food, and cattle newly introduced into strange pastures in quarters of the globe far distant from their native soil are liable to be poisoned by strange herbs, which, however, after a time they learn to avoid.

The generalised food-customs of mankind are therefore not to be viewed as random practices adopted to please the palate or to gratify an idle or vicious appetite. These customs must be regarded as the outcome of profound instincts, which correspond to important wants of the human economy. They are the fruit of a colossal experience, accumulated by countless millions of men through successive generations. They have the same weight and significance as other kindred facts of natural history, and are fitted to yield to observation and study lessons of the highest scientific and practical value.

In taking dietetic customs as objects of study it is obvious that widely disseminated customs, followed by many races and by vast masses of population, have a deeper and wider significance than customs limited to small communities or to isolated familes or individuals. It is also obvious that the practices of the more successful races, and of the easier classes of a nation, are more likely to yield good dietetic models than the practices of backward races, or of the poorer classes. Because the former, owing to their ampler means, have greater freedom of choice, and because also their greater success in the struggle for predominance is *primâ facie* evidence of the beneficial tendency of their food-habits. I need hardly say that dietetic customs which are not the outcome of the free choice of the population, but are the consequence of legislative enactments or of religious injunctions, are of no utility as guides in the study of dietetics—except, indeed, as warnings of the mischief that may accrue from ignorant meddling.

The British races and the other races of Western Europe, together with their descendants in different parts of the globe, are, on the grounds just stated, fitted to supply us with a body of dietetic customs which may be regarded as a beneficial model. These races and nations are, on the whole, but especially in intellectual power, far in advance of all others. Their food-customs have grown up spontaneously, without material interference from legislator or religious reformer. Their world-wide commerce has brought cheaply to their doors the products of every land and every clime, and has enabled them to exercise a greater freedom of selection than has been possible to any other races.

The salient characteristics of the diet of the Western races may be expressed in a few words. It consists partly of cereal and farinaceous articles and fruit, and partly of animal flesh. The use of alcoholic beverages is almost universal among them, and they consume, in large quantity, tea, or coffee, or cocoa, or all three. I propose to make a few remarks on each of these characteristics.

THE USE OF MEAT.

It has been estimated that among the easier classes in Western Europe about one-fourth of their food consists of meat or fish, and three-fourths of vegetable articles and fruit. In this, our own country, the consumption of meat is considerably larger than on the Continent of Europe.[1]

---

[1] The consumption of meat per head per annum is estimated as 136 lbs. in England, 46 lbs. in France, 35 lbs. in Prussia, and 84 lbs. in

This consumption is also steadily increasing. The increase, however, is not due to any change of habits among the easier classes, but to an increasing use of meat among the working classes. As wages improve the diet of the working classes tends to become more and more assimilated to that of the easier classes. Among the latter it may be said that a state of stable equilibrium in regard to this point has been attained, or at least approached, and that meat constitutes as large a part of their dietary as it is likely to reach. But with the larger part of the population this is far from being the case. Meat is a dear form of food. In regard to proteid matter, lean beef contains, roughly speaking, twice as much as wheat flour, but beef is about four times as dear as flour, so that you may estimate that proteids of animal source are about twice as costly as proteids of vegetable source. The want of means among the poorer classes prevents this part of the population from indulging in meat to the full length of their desires. The proportion of meat which enters the households of the easy classes is greatly in excess of that which enters the households of the less affluent. We should not probably be far out in estimating that if the entire population consumed as much meat per head as do the wealthier portions the total consumption of meat in this country would be increased threefold.

THE USE OF ALCOHOL.

The use of alcoholic beverages is a marked characteristic of the diet of the European and other progressive races. The vast populations of Asia, with the exception

---

Belgium. It is larger in cities than in rural districts, and is largest of all in London.—*Condition of Nations*, by Kolb, p. 961.

of the Japanese[1] and the Indian Parsees,[2] are almost non-alcoholic in their habits. This is largely due to the prevalence of the tenets of Islam throughout Asia and the injunctions against the use of wine in the Mahommedan system. There is an impression that the British races enjoy a bad pre-eminence for their use of alcohol. But this impression is not borne out by exact inquiry. It would appear from the most reliable statistical returns that there is a considerable uniformity in the consumption of alcohol, per head of the population, among the nations of Europe. Mr. Mott estimates the average consumption of alcohol among the civilised nations as between four and five gallons of proof spirit per head per annum.[3] But although the total consumption of alcohol in this country be not excessive for the entire population, a larger number of individuals take an excessive quantity than is the case among most of our neighbours across the Channel.

There are certain inferior races who appear to be altogether intolerant of alcohol. Either it does not suit their type of nutrition or they lack the self-control which is necessary to its beneficial use. The Indians of North

---

[1] Saké, the national beverage of the Japanese, is a kind of strong beer, containing about 10 per cent. of alcohol, brewed from rice by a peculiar method, quite different from the processes used in Europe. The consumption of saké in Japan is on a very large scale, and the Government derives about a sixth of its revenue therefrom. Mr. R. W. Atkinson, formerly Professor of Chemistry in the University of Tokio, estimates that the Japanese consume per head about one-third as much alcohol in the form of saké as is consumed in England in the form of beer. Saké brewing is known to have existed on a large scale in Japan for 300 years.—Memoirs of the Science Department of the Tokio University, No. 6. *The Chemistry of Saké Brewing*, by R. W. Atkinson, printed at Tokio, 1881.

[2] The habits of the Indian Parsees in regard to the use of alcohol seem to resemble those of temperate Europeans.—See *History of the Indian Parsis*, by Dosabhai Framji Karaka: London, 1884.

[3] A. T. Mott.—*National Review*, May, 1884, p. 296.

America are said to be excited almost to madness by any use of alcohol, insomuch that the Colonial authorities forbid, under heavy penalties, the giving or selling of alcoholic liquors to the native tribes. The Ainos of Yezo, a subject race inhabiting the northern island of Japan, appear to be wholly wanting in self-control in the use of alcoholic stimulants, for which they evince an irrepressible passion. Whenever they have the opportunity, both the men and the women drink themselves to a state of insensibility.[1] The defective reaction of these races towards alcohol may be compared to a similarly defective reaction in certain individuals and certain families among ourselves.

THE USE OF TEA, COFFEE, AND COCOA.

Within the last two centuries an important change has taken place in the dietetic customs of the European nations through the introduction of tea, coffee, and cocoa. The use of these beverages has spread rapidly among the populations, and at the present day they are articles of large and almost universal consumption. In this country all three beverages are in common use side by side, but tea takes a large and increasing lead, especially among the working classes. On the Continent the use of one or other of these beverages prevails almost to the exclusion of the rest; in France and Germany coffee prevails, in Russia tea, and in Spain and Italy cocoa or chocolate.

The introduction of these articles constitutes, without doubt, the most remarkable dietetic revolution witnessed among men in historic times. Within the last hundred years the use of these beverages has become so large and so general that we may fairly assume that a sufficient time has elapsed to enable us to form a judgment of their effects on national characteristics. That the effects have not been injurious to the nations of Europe is demonstrated by the continued progress of these nations, and their increasing ascendency among the nations of the world. It is scarcely possible that so important and so peculiar an addition to our dietary has not had some effect on the type of nutrition, and more particularly on the nutrition of the brain and nervous system. Reflecting on this matter, I have not been able to avoid the impression that it is possible to trace a change in the mental type of the Western races in the last three generations. There is, I think, to be observed an increased precision in their mental operations, resulting in an improved criticism, and in the rise and progress of the exact sciences. It is certainly remarkable that within the last century, coincident with the spread of tea, and coffee, and cocoa, and perhaps I should add tobacco, and in combination with the ancient usage of alcohol, there has been, within this brief epoch, more progress made in criticism and the exact sciences and the dependent industrial arts, than in all the preceding ages of the world; whereas, during the same epoch, art and literature, which depend more on the imagination, have practically stood still. The coincidence is at least suggestive.

---

[1] *Unbeaten Tracks in Japan*, by Miss Bird, vol. ii.

It is to be noted that (at least among the English-speaking communities) the general custom with regard to tea and coffee is to take these beverages in the morning and afternoon, whereas with regard to alcohol the custom is reversed. As a rule, alcoholic beverages are not taken before the mid-day meal, and the larger portion of the daily consumption is reserved for the last meal and for the period intervening between that meal and bed-time. The reason of this is obvious. Tea and coffee tend to promote wakefulness; alcohol, on the other hand, in the second phase of its effects, tends to lethargy and the promotion of sleep.

DIETETIC HABITS OF THE TWO SEXES, OF INFANTS AND CHILDREN, AND OF THE AGED.

There is a clear difference to be discerned in the dietetic habits of the two sexes. There are no available statistical data to go upon; but from common observation we cannot fail to note that men eat much more meat than women. Probably we should not err in estimating that two-thirds of the meat brought to market is eaten by the men, and only one-third by the women. In regard to alcohol, the contrast is still more marked. My impression is that, in this country, three-fourths, if not four-fifths, of the alcohol is consumed by men, and only one-fourth or one-fifth by the women. On the other hand, the consumption of tea and coffee—but especially of tea—is markedly more abundant among women than among men. The comparison is completed when we add that women consume, in proportion to the totality of their food, more milk and more bread than men do.[1]

Alongside the main dietetic habits established for the profit of the operative mass of the community there are secondary habits formed for the use of infants and children, and for persons advanced in years. With regard to infants and children, we observe that they are not allowed to partake of the accessory articles of food which form so conspicuous a part of the dietary of their elders. They are allowed neither the use of alcohol nor of tea and coffee, except gradually as they draw towards the adult age, but are fed on simple nutrients—milk, cooked cereals, and more or less meat.

---

[1] If I am not mistaken, these contrasts in the diet of the two sexes are more pronounced in this country than in most others; and there is, perhaps, to be observed a corresponding breadth of contrast between the characteristics of the two sexes—the men being less effeminate and the women more womanly with us than among some other populations.

With advancing years the diet undergoes a certain modification. The consumption of meat is, I think, generally lessened, and the consumption of milk and cooked cereals proportionally increased. In regard to alcohol, the modification of habit seems to vary with the preceding practice of the individual. Persons who have been in the habit during their prime of taking a full allowance of stimulants gradually diminish the proportion as age creeps on and their nutritive processes decline in elasticity and power. Sometimes the indications of this natural tendency are neglected or resisted by the unwary; they imagine that the quantity of stimulants which they tolerated with impunity, or even took with advantage, during the vigour of manhood cannot hurt them in later life. This, I believe, is an error the commission of which tends to accelerate senile decay and to provoke fatally tending organic changes in the kidneys, liver, and arterial system.

On the other hand, persons who during their youth and prime have only used alcohol occasionally, or have abstained entirely from it, find advantage in their declining years in a more systematic use of wine or spirits.

It is important to remark that the main dietetic customs of a country are instituted for the benefit of the robust and healthy, of the sober and temperate, and those of mean or average constitution; in other words, for those who are bearing the burden of the day and fighting the battle of life. These form the great mass and bulk of the adult population, upon whose bodily and mental efficiency national progress and ascendency depend. A good many individuals, and even entire families, may not find these customs beneficial to their exceptional tendencies or weaknesses; they may even find them destructive to their health and life; but here as elsewhere, and indeed universally, in Nature's operations the individual is sacrificed to the welfare of the community—

> So careful of the type she seems,
> So careless of the single life.

It would not appear to be the part of wisdom to depart without some solid reason from the dietetic customs of the country. We may be quite sure that the use of meat and of alcoholic beverages, and of tea and coffee, subserve some useful purposes to the human economy; though we, in our ignorance, may not be able to specify them with precision. These customs are the spontaneous outcrop of natural instincts and the fruit of an immense experience; and the sanction they derive therefrom constitutes an incomparably weightier authority than any other we possess.

Nevertheless differences of constitution and personal idiosyncrasies have to be reckoned with; and there are frequently good, indeed paramount, reasons why individuals should, in some particular or other, depart from the general dietetic plan. I have known a few natural-born vegetarians who have had a life-long distaste for meat.[1] Some persons are intolerant of tea, others are intolerant of coffee. It is, however, with respect to alcohol that the most important deviations from the mean type of constitution occur. Some persons are made uncomfortable by the most sparing use of alcohol, either throughout their life or at some epoch of it. A good many also are wanting in that self-control which is necessary to the salutary use of this stimulant. These peculiarities or idiosyncrasies must be attended to. It may be regarded as certain that any food or food-accessory the use of which is followed by a sense of discomfort is not beneficial to that individual. Persons who are unable to take alcohol in moderation should, on pain of loss of health and life, altogether abstain from its use, for to them it is easier to abstain than to be abstemious.

---

[1] It is not very uncommon to meet with children who have an aversion to meat, and who require considerable training on the part of their parents to accustom them to its use.

EFFECT OF THE QUALITY OF THE FOOD ON NUTRITION AND VITAL HABITS.

There are some very subtle and exceedingly curious relations between the quality of the food and the nutrition and vital habits of the body. They are profoundly difficult to understand, and yet are absolutely authentic and highly important. One would think that so long as an animal obtained his due quantity of proteids, carbohydrates, and fats, it did not matter much from what source they were obtained. But this is far from being the case. There are differences in effect not only between animal and vegetable articles of food, but also between one kind of animal food and another, and between one kind of vegetable food and another.

A remarkable illustration of the effect of the quality of the food on nutrition is supplied by the honey-bee. It is well known that when by some untoward accident a hive loses its queen the community have the power of providing themselves with a new queen. This is effected in the following manner. They take one of the ordinary neuter eggs, which in the usual course would produce an imperfect female or 'worker' bee, and place it in a peculiarly shaped cell, and feed the larva when hatched with a peculiar kind of food which bee-keepers term 'Royal Jelly.' The ordinary worker larva only gets one meal—its first—of this dainty, and is afterwards fed with some coarser stuff, but the intended queen is fed throughout her larva-ship with royal jelly. The consequence of this difference of diet is that the larva so fed comes quickly to maturity, and, instead of turning out a neuter, turns out a fertile female, or queen-bee.[1]

Other illustrations are furnished by our domestic animals. Experience has taught trainers that the vital habits and qualities of horses and dogs are considerably modified by the nature of their food. The characteristics of each strain are transmitted by heredity, but in order that they may be maintained in perfection the offspring must be fed with appropriate food. Trainers will tell you that the hunter and the draught-horse require to be fed differently. The hunter is bred and fed for speed and carrying power; the draught-horse for bulk and strength. In the hunter is wanted rapid liberation of energy within a comparatively short space of time; in the draught-horse is wanted a more gradual liberation of energy and for a longer period. To bring out their qualities each strain must be fed appropriately. The hunter is fed on a concentrated and stimulating form of food—chiefly on the heaviest and most expensive oats—which, if I may so express it, is the 'beef' of the vegetable feeders; and, unless he is so fed, he will not perform satisfactorily in the hunting-field. The draught-horse is fed on a lower and less stimulating diet—on Indian corn and chopped hay—food which tends to increase bulk and weight.

---

[1] 'It is well known that hemp-seed causes bullfinches and certain other birds to become black. Mr. Wallace has communicated to me some much more remarkable facts of the same nature. The natives of the Amazonian region feed the common green parrot with the fat of large Siluroid fishes, and the birds thus treated become beautifully variegated with red and yellow feathers. In the Malayan Archipelago the natives of Gilolo alter in an analogous manner the colours of another parrot, namely, the *Lorius garrulus*, Linn., and thus produce the *Lori rajah*, or King-Lory. These parrots in the Malay Islands and South America, when fed by the natives on natural vegetable food, such as rice and plantains, retain their proper colours.'—Darwin *Animals and Plants under Domestication*, vol. ii., p. 269.

Slow-going sporting dogs—setters and harriers—are fed chiefly on oatmeal and weak broth, but the coursing greyhound is trained on the very best of beef and mutton; and if these distinctions in the feeding are not observed neither kind comes up to its best performances.

These differences are expressed in popular phrase by saying that the hunter and the coursing greyhound are 'high-fed,' and the draught-horse and sporting-dog are 'low-fed.' The same kind of distinction may be drawn in regard to the diet of different members of the human family; some are high-fed and some are low-fed. Speaking generally, it may be said that high-feeding, in the case of man, consists mainly in a liberal allowance of meat and in the systematic use of alcoholic beverages, and that low-feeding consists in a diet which is mainly vegetarian and non-alcoholic. On the ground of this distinction it may be said that the European races are more highly fed than the Asiatic, that the British races are more highly fed than the Continental races, and that the inhabitants of London (owing to their large consumption of meat) are the most highly fed population in the world. The easier classes are more highly fed than the poorer classes, the town artisan is more highly fed than the agricultural labourer.

In drawing this contrast between high-feeding and low-feeding, the distinction has reference solely to the quality and not to the quantity of the food—to its comparative stimulating properties and concentration. It should also be remarked that it is the every-day habit that determines the character of the diet, and not occasional indulgence. A man may drink alcohol to excess or gorge himself with meat once a week or now and then, and yet have a low general standard of diet. Another man may be a spare liver, but if he take regularly meat three times a day, and drink daily of high-class wines or spirits, even in the most modest proportion, his diet must be ranked as high. There are distinctions also to be drawn in regard to the several kinds of meat and the several kinds of vegetable articles used. Beef and game should probably be ranked as a higher diet than poultry and fish, and oats and wheat as higher than rice and potatoes.

If we compare, as best we may with our limited information, the general characteristics of the high-fed and low-fed classes and races, there is, I think, to be perceived a broad distinction between them. In regard to bodily strength and longevity the difference is inconsiderable; but in regard to mental qualities the distinction is marked. The high-fed classes and races display on the whole a richer vitality, more momentum and individuality of character, and a greater brain-power, than their low-fed brethren; and they constitute the soil, or breeding-ground, out of which eminent men chiefly arise.[1]

In calculating what may be termed the 'man-value' of individuals, classes, or races, physical qualities count for relatively little. One man may be twice as strong, or twice as big, or possess twice as much muscular endurance, as another; but the difference of value scarcely goes beyond, and rarely even reaches, this proportion. But the possible difference between the mental capacity of one man and another is immense, almost incalculable. If you try to assess and to compare the value or capacity of a man of eminence—whether it be eminence in art, literature, science, statesmanship, commercial enterprise, colonising aptitude, military command, or any other outcome of brain-power, with the value and capacity of an average man, you perceive at once that the proportion is not as two to one—but as ten or twenty to one, or even as a hundred or more to one.

---

[1] It is remarkable how often we hear of eminent men being troubled with gout, and gout is usually produced either by personal or ancestral high feeding.

Galton, in his interesting and original work on 'Hereditary Genius,' gives a telling illustration of the possible degree of difference in mathematical capacity between different individuals. He takes the number of marks given to the several candidates in the examination for mathematical honours at the University of Cambridge, and shows that the senior wrangler exhibits a mathematical capacity thirty or thirty-two times greater than the lowest on the list of honours; and this last must be credited with a mathematical capacity many times greater than that of the average undergraduate.

Differences in mental capacity are referable on ultimate analysis to differences in the type of nutrition of the brain-cells; and nutrition, as we have seen, is influenced in a very subtle manner by the quality of the food. It is to be borne in mind that, a certain type of nutrition having been acquired, it tends to become intensified and fixed by a continuance of the conditions which originated it and to be transmitted by heredity. The effects of dietetic habits are not therefore made fully apparent in a short time, nor are they easily nor soon nullified by a change of diet. Gout furnishes an illustration of these propositions. Gout is a type of nutrition liable to be acquired by persons who indulge in a certain kind of high-feeding. The gouty tendency gradually grows under a continuance of the gout-producing diet, until at length it reveals its presence in an arthritic attack. But a person so afflicted cannot easily nor soon throw off his gout by reverting to a low scale of feeding; it is often stamped on his constitution for life, and is handed on to his posterity.

Similarly with types of nutrition produced by a low standard of diet. The effects of a vegetarian diet or of a non-alcoholic regimen would only be gradually developed, and would probably not be fully impressed on the bodily and mental qualities of the race until after such habits had been continued through two or three successive generations.[1]

---

[1] I have encountered in Salford, where some years ago there existed a flourishing colony of vegetarians, a tradition to the effect that though vegetarianism might suit the parents it was bad for the children. And I have seen some striking examples in that borough which appeared to indicate that this tradition was well founded.

II.

EFFECT OF FOOD-ACCESSORIES ON SALIVARY DIGESTION.

(Second Lecture of the Owens College Course.)

SUMMARY:—Preliminary remarks—Richness of human saliva in diastase connected with the habit of cooking food—Method of experimentation—Effect of alcohol and ardent spirits on salivary digestion—Wines—Vinegar—Malt liquors—Effervescent table waters—Tea and coffee—Tannin—Effect of carbonate of soda on tea, and of the effervescent table waters on wine—Beef-tea, salt, and sugar.

HAVING disposed of these general considerations, I now turn to the examination of some of those problems which are special to human dietetics, and which are not presented to us at all in the study of digestion in the lower animals. We have seen that the civilised races are in the habit of using with their food certain accessory articles of a stimulant or restorative character, which have no title to be regarded as nutrient substances. These form no part of the diet of the lower animals, nor are they necessary or essential to our own diet. Nevertheless they are consumed by us in enormous quantities, and at a prodigious cost.

What is the effect of these several accessories on the processes of digestion? Do they help, or do they hinder, or are they indifferent?

These are the questions I propose to consider. Digestion, as you know, is carried on in three successive stages *or phases*: in the mouth under the influence of salivary diastase, in the stomach under the influence of pepsin and hydrochloric acid, and in the small intestine under the influence of the pancreatic juice. I shall take these stages in succession, and inquire in each case what is the effect of our various food-accessories on these several phases of the digestive process.

EFFECT OF FOOD-ACCESSORIES ON SALIVARY DIGESTION.

Salivary digestion consists in the transformation of starch into sugar. It takes place partly in the mouth during the process of mastication and partly in the stomach on the arrival of the food in that viscus, and it continues to go on until the rising acidity of the gastric contents puts a final stop to diastasic action. The time of salivary digestion is therefore brief, and to be of any avail the action must be energetic. The digestion of starch by saliva is never more than partial; and seeing that the pancreatic juice lies in reserve in the duodenum, and that this has an intense amylolytic activity, it is obvious that starchy matters would not fail of being digested even if they were not subjected at all to salivary action. Some physiologists have even doubted, on the ground of observations on animals, whether the action of saliva on starch is of any importance. But it is to be remarked that human saliva is peculiarly rich in diastase, richer apparently than the saliva of any other creature. And this wealth of diastase, we may be sure, is not there for nothing. If salivary diastase were of no service, it would, in accordance with a well-known biological law, soon fall into abeyance and cease to be secreted. It can scarcely be doubted, I think, that the exceptional richness in diastase of human saliva has special relation to the habit man has acquired of cooking his food. Salivary diastase is powerless on raw starch, but it acts energetically on starch which has been changed to a state of jelly or mucilage by previous boiling or baking. And if we consider how large a part of our food consists of bread and other cooked farinaceous articles the importance of our exceptional salivary power will at once appear. The first step in amylolysis is to change starch jelly into soluble starch, and this first step is accomplished with extreme rapidity; and although it is only the initial act in the transformation of starch, the physical alteration so produced is very great and of important advantage in the subsequent stages of digestion. By this initial act the solid or semi-solid coherent starch jelly is transformed into a running liquid. Such articles as bread, pastry, and doughy puddings are altered considerably even by a brief contact with saliva. Their texture is rendered looser and more penetrable, and this change greatly facilitates the subsequent task of the gastric juice.

Method of Experimentation.—In testing the effects of food-accessories on starch digestion I followed the method of diastasimetry described in the preceding section (*see* p. 68 *et seq.*). I operated on a 'standard starch mucilage,' which contained exactly 1 per cent. of dry starch. Ten cubic centimeters of this standard starch mucilage were diluted with 90 cubic centimeters of water. This was called the 'digesting mixture.' To this was added 1 cubic centimeter of filtered saliva, and the time of the addition was exactly noted. Digestion soon began, and went on apace. From time to time a drop of the digesting mixture was placed on a white porcelain surface and touched with a drop of solution of iodine. At first the well-known dark blue coloration was produced by the contact. In a minute or two the coloration produced was no longer blue, but violet, in another minute it was fawn, and then very pale yellow, and finally in four or five minutes from the commencement of the experiment the abstracted drop gave no coloration at all with iodine; all the starch had been converted into colourless dextrine and sugar. The time when this occurred was exactly noted—this was called the 'achromic point.' The length of time required to reach the achromic point furnished a measure of the speed, or activity, of digestion. The experiments were always performed at or near blood-heat. When I wished to try the effect on starch digestion of a food-accessory, say tea, I added a known quantity of the infusion to the 90 cubic centimeters of dilution water, or rather I included it in this, so that the total digesting mixture always amounted to 100 cubic centimeters. The single cubic centimeter of saliva was next added.[1] I could then see, by the length of time required to reach the achromic point, whether the addition I had made hastened or retarded digestion, or was indifferent. Operating in this way I tested the effect on salivary digestion of varying proportions of alcohol, wines, tea, coffee, salt, vinegar, &c.

ALCOHOLIC BEVERAGES.

Alcohol, Whisky, and Brandy.—Alcohol was used as 'proof spirit' containing exactly 50 per cent. of absolute alcohol. The whisky used was marked 'proof'—the brandy was 10 under proof. Gin was found to have nearly the same effect as a watery dilution of corresponding alcoholic strength. I have not therefore thought it necessary to give separately the results obtained with gin. The following table exhibits the results obtained :—

---

[1] The same specimen of saliva was always employed for the same set of experiments. Specimens of saliva from the same individual were found to vary very little in diastasic power.

TABLE I.—*Showing the effects of Alcohol and of Brandy and Whisky on Salivary Digestion.*

10 c.c. standard starch mucilage + varying quantities of proof spirit, brandy, or whisky + water up to 100 c.c. + 1 c.c. of filtered saliva.

Proportion of Proof Spirit, Brandy, or Whisky in the Digesting Mixture	Time in which the achromic point was reached (Normal, 4 minutes)		
	Proof Spirit	French Brandy	Scotch Whisky
5 per cent. . .	4 minutes	4 minutes	4 minutes
10 " . .	4 "	very slow action	30 "
20 " . .	4 "	no action	very slow action
40 " . .	8 "	"	no action
60 " . .	14 "	"	"
70 " . .	20 "	"	"
90 " . .	very slow action	"	"

The indicated 'normal' of four minutes inserted at the head of the columns signifies that with simple water, without any foreign addition, the achromic point was reached in four minutes at blood heat. The first column shows the action of alcohol, merely diluted with water, and it is seen that the influence is extraordinarily slight. When the proportion of proof spirit amounts to 20 per cent. there is a slight precipitation of starch ; this increases as the proportion of alcohol rises until, with 90 per cent. proof spirit, there was almost total precipitation of starch. This precipitation evidently interferes with the activity of the ferment ; but, even with 90 per cent. of proof spirit in the digesting mixture, there was some action, and sugar could be detected after a while in the mixture ; gin gave approximately the same results as proof spirit. But brandy and Scotch whisky showed an inhibitory effect greatly out of proportion to the quantity of alcohol contained in them; and brandy was sensibly worse than whisky. The cause of this discrepancy does not depend on the slight acidity of these spirits, for I obtained the same results when this was neutralised. It seems to be owing chiefly to certain ethereal bodies and volatile oils contained in them. In the case of brandy the retarding effect depends partly on a trace of tannin which that spirit always contains; and tannin, as we shall presently see, has an intense inhibitory effect on salivary action.

Looking at these results, it would not appear that ardent spirits, as used dietetically, hamper salivary digestion, but rather promote it by causing an increased flow of saliva. A tea-spoonful of brandy or whisky, introduced into the mouth, can be perceived at once to cause a gush of saliva. The common practice of adding a table-spoonful of brandy to a basin of arrowroot or sago gruel, therefore, promotes its digestion; but the proportion should not much exceed five per cent., and gin is evidently a preferable addition to brandy or whisky. Brandy and whisky precipitated the starch more readily than proof spirit or gin.

Wines.—Both the stronger and the lighter wines showed a powerful inhibitory effect on salivary digestion. Even so small a proportion as 1 per cent. of sherry or hock was found to paralyse saliva almost completely, and even one half or one quarter of this proportion delayed the achromatic point appreciably. Claret and port wine behaved similarly. The inhibitory effect of wines is entirely due to the very considerable degree of acidity which they all possess. In the preparation of white wine whey we are in the habit, unconsciously, of utilising the acidity of sherry to break the hot milk, for it is not the spirit contained in the wine, but its acid, that causes the milk to curdle. When the acidity of wines is neutralised they lose entirely their inhibitory effect on salivary digestion.

TABLE II.—*Exhibits the results obtained with Sherry and Hock on Salivary Digestion.*

10 c.c. standard starch mucilage + varying quantities of sherry or hock + water up to 100 c.c. + 1 c.c. saliva.

Proportion of Sherry or Hock contained in the Digesting Mixture	Time in which the achromic point was reached (Normal, 4 minutes)	
	Sherry	Hock
0·25 per cent.	8 minutes	16 minutes
0·5 „	30 „	80 „
1· „	no action beyond soluble starch	no action beyond soluble starch
2· „	no action	no action
40· „ neutralised	4 minutes	4 minutes

Action of Acids on Salivary Digestion.—This is a question of considerable interest—not only because we are in the habit of using acid wines and malt liquors with our food, but also vinegar and pickles and lemon-juice; and eat puddings and pies containing acid fruits or acid rhubarb stalks.

The annexed table shows the effect of table vinegar on salivary digestion:—

TABLE III.—*Effect of Table Vinegar on Salivary Digestion.*

10 c.c. standard starch mucilage + varying quantities of vinegar + water up to 100 c.c. + 1 c.c. filtered saliva.

Proportion of Vinegar contained in the Digesting Mixture	Time in which the achromic point was reached (Normal, 4 minutes)
0·02 per cent. = 1 in 5,000	6 minutes
0·05 „ = 1 in 2,000	14 „
0·1 „ = 1 in 1,000	30 „
0·2 „ = 1 in 500	no action

The table shows that the hindering effect of vinegar is very powerful. Even so small a proportion as 1 in 5,000 sensibly delayed the action; with a proportion of 1 in 1,000 the action was very slow, and it was altogether arrested when the proportion of vinegar rose to 1 in 500.

The bearing of these results on the use of salads is evident. Salads are usually highly seasoned with vinegar, and they are commonly eaten with a liberal use of bread. The acid may perhaps assist in the digestion of the salad; but it is obvious that it would altogether prevent any salivary action on the bread eaten with it. This, of course, is a matter of no moment to a eupeptic individual, who has abundant digestive resources; but those of weak digestion would do well to be sparing in the use of acid salads and other sour dishes.

Malt Liquors.—Malt liquors were found to hamper salivary digestion exactly in proportion to their degree of acidity. Sound English beers have not nearly so much acidity as wines—and they interfere comparatively little with the digestion of starch; but 'turned' beer is highly inhibitory.

Effervescent Table Waters.—The examination of these yielded some odd results. A pure aerated water, charged merely with carbonic acid, exhibited considerable inhibitory power on salivary action. When the digesting mixture contained 50 per cent. of a carbonated water the diastasic action was wholly arrested, and even so small a proportion as 10 per cent. postponed the achromatic point from the normal of four minutes to thirty minutes. But the effervescent table waters of commerce—soda water, potash water, seltzer water, Apollinaris water, &c.—are all more or less charged with alkaline carbonates; and this charge of alkali altogether removes their inhibitory effect on salivary digestion. These waters are, as you know, extensively used both here, and still more on the Continent of Europe, as an addition to wines—to claret, hock, and sherry especially. And the effect of this addition is to greatly mitigate, or wholly to obviate, the retarding influence of these wines on the digestion of starch. The use of these waters as an addition to wines is, therefore, highly commendable.

TEA, COFFEE, AND COCOA.

The effect of tea and coffee on salivary digestion presented a strong contrast, for while tea exhibited an intense inhibitory action, coffee—and with it may be ranged cocoa—had only a subordinate effect. As this is the first time I have had occasion to speak of experimental inquiries into the effect of these beverages, I must enter into a little explanation. There is no standard strength of tea and coffee, but from information gathered in the social circle, and observations on the beverages put on my own table, I have learnt that the medium strength of tea is from 4 to 5 per cent., that is, four or five parts by weight of the dry leaf to a hundred parts of boiling water. Strong tea runs up to about 7 per cent., and weak tea goes down to 2 per cent. Coffee is generally used in a stronger infusion than tea. Medium coffee has a strength of about 7 per cent., and strong coffee—the black coffee or 'Café noir' of our French neighbours—has a strength of about 12 or 15 per cent. Cocoa, on the other hand, is usually made weak; the printed directions given on the packets of cocoa indicate a strength of only about 2 per cent. This is probably one of the reasons why cocoa has a higher reputation as an aid to digestion than tea or coffee.

TABLE IV.—*Effect of Tea and Coffee on Salivary Digestion.*

10 c.c. standard starch mucilage + varying quantities of tea and coffee (both of 5 per cent. strength) + water to 100 c.c. + 1 c.c. filtered saliva. Both beverages were infused for ten minutes and then filtered.

Proportion of Tea or Coffee contained in the Digesting Mixture	Time in which the achromic point was reached (Normal, 4 minutes)	
	Tea—5 per cent. strength	Coffee—5 per cent. strength
1 per cent. . . .	8 minutes	4 minutes
2 ,, . . .	30 ,,	4 ,,
3 ,, . . .	50 ,,	4 ,,
5 ,, . . .	180 ,,	4 ,
10 ,, . . .	no action beyond soluble starch	4 ,,
20 ,, . . .	no action	4 ,,
40 ,, . . .	—	10 ,,
60 ,, . . .	—	20 ,,

Tea.—The table shows that tea is a powerful retarder of salivary digestion. When the digesting mixture contained even so small a proportion as 1 per cent. there was a perceptible retardation, and as the proportion increased the inhibitory effect was rapidly intensified. With a proportion of 2 and 3 per cent. the achromatic point was delayed from the normal of four minutes to thirty and fifty minutes respectively; with 5 per cent. it was delayed to three hours, and above this proportion there was practically no digestion of starch. A specimen of high-class Assam tea was found to retard salivary digestion somewhat more powerfully than a good China tea. A very cheap low-class tea costing 1*s*. 6*d*. per lb., such as is supplied to the poorest classes, had very little retarding effect. It was probably an adulterated article.

What is the cause of the inhibitory action of tea on salivary digestion? It seems to be entirely due to the large proportion of tannin contained in tea. Black

China tea contains, according to the analyses of Jauke, an average of 8 per cent. of tannin;[1] and, as the following table shows, tannin is highly inimical to the digestion of starch.

TABLE V.—*Shows the effect of Tannin on Salivary Digestion.*

10 c.c. standard starch mucilage + varying quantities of tannin + water to 100 c.c. + 1 c.c. filtered saliva.

Proportion of Tannin in the Digesting Mixture	Time in which the achromic point was reached (Normal, 4 minutes)
0·002 per cent. = 1 in 50,000 .	10 minutes
0·005 ,, = 1 in 20,000 .	40 ,,
0·01 ,, = 1 in 10,000 .	no digestion beyond soluble starch
0·02 ,, = 1 in 5,000 .	no digestion

On comparing the results obtained with tea and those obtained with tannin, and calculating the amount of tannin which would be contained in a 5 per cent. infusion of tea, the conclusion is arrived at that the tannin contained in tea fully accounts for its inhibitory effect on salivary digestion. For if the tea operated with contained 8 per cent. of tannin, and three-fourths of this were taken up in the infusion, it would yield a solution containing 0·3 per cent. of tannin, and the effect of such a percentage of tannin would correspond very exactly with the results shown by experiment to be produced by the tea employed. It appears that tannin exists in two conditions in the tea-leaf. One, the larger, portion is in the free state, and is easily extracted by hot water; but about one-fourth is fixed and remains undissolved in the fully exhausted tea-leaves. Some persons have supposed that by infusing tea for a very short time—only two or three minutes—the passing of tannin into the infusion could be avoided. This is a delusion; you can no more have tea without tannin than you can have wine without alcohol. Tannin, in the free state, is one of the most soluble substances known. If you pour hot water on a little heap of tannin it instantly dissolves like so much pounded sugar.

---

[1] Walter Blyth, *Foods, their Composition and Analysis*, p. 334.

Tea-leaves when treated with hot water expand at once into thin broad laminæ, presenting a highly favourable condition for the rapid extraction of their soluble constituents. Tea infused for two minutes was not found sensibly inferior in its retarding power on salivary digestion to tea infused for thirty minutes. The deterioration of the flavour of tea by long infusion appears to depend on the slower taking up of a bitter principle, which is less soluble than tannin, and which, apparently, does not interfere with diastasic action. If you wish to minimise the inhibitory action of tea on starch digestion you should direct, not that it be infused for two or three minutes, but that it should be made very weak and used very sparingly, and that it should be drunk, not with the meal, but after the meal has been swallowed. There is a curious difference in the practice of different persons in the way in which they imbibe beverages with their meals. Some drink and eat at the same time; others eat first and drink afterwards. The latter are the wiser if it be an object to facilitate their salivary digestion.

There is another device by which the inhibitory effect of tea on salivary digestion may be obviated, and which may be recommended to persons of weak digestion. The introduction of a pinch of bicarbonate of soda into the teapot completely removes the deterrent effect of tea on starch digestion. This is a practice I have seen followed in some households under the idea that the soda helps to extract the virtue of the tea. I found on experiment that the addition of so small a proportion as 1 per cent.

of bicarbonate of soda to the weight of the dry tea-leaf greatly mitigated the inhibitory effect of the infusion on starch digestion, and that twice this quantity (2 per cent.) almost entirely removed it. This latter proportion corresponds roughly to about ten grains of soda (as much as will stand on a threepenny-piece) to an ounce of the dry tea-leaf. A darker coloured infusion is obtained thereby, but the flavour is not sensibly altered, nor is there an alkaline reaction produced—for tea-infusion, like most other vegetable infusions, is slightly acid to test paper; and the quantity of soda here mentioned is only just sufficient to neutralise that acidity. But is the inhibitory effect of tea on starch digestion injurious to healthy people? Is not this retarding effect really one of the objects which we unconsciously aim at in using this beverage? I will return to these questions later on when I come to consider the effects of our food-accessories on peptic digestion.

The peculiar alkaloid of tea—theine or caffein, for the two bodies are identical—and the volatile oil which gives it aroma, seem to have no part in the inhibitory effect of tea on digestion. I made direct experiments with citrate of caffein, and found it indifferent, at least in such proportions as it could ever be present in our tea infusions. I tested the effect of theine and the volatile oil in another way. I sprinkled some dry tea-leaf on a plate and exposed it for four hours to a temperature of 212° Fahr. (100° C.). This would suffice to drive off both the alkaloid and the volatile oil. Tea so treated was found to have lost none of its inhibitory effects on starch digestion.

Coffee.—Coffee was found to have a far less inhibitory action on salivary digestion than tea (see Table IV.). Operating on a 5 per cent. infusion of a high-class coffee, it was found that up to a proportion of 20 per cent. in the digesting mixture there was no appreciable retarding effect. With 40 per cent. the achromic point was delayed from the normal of four minutes to ten minutes. Above this point the retarding effect increased somewhat; but even when the digesting mixture contained 90 per cent. of coffee digestion still went on with considerable speed. In coffee, tannin is replaced by a modification of that substance called caffeo-tannic acid, and this accounts for the marked difference in the effect of the two beverages on salivary digestion.

Cocoa resembles coffee in its effect on starch digestion, and it may be regarded as practically indifferent. We may therefore infer from these observations that the use of coffee and cocoa, in so far as concerns their influence on salivary action, is more to be recommended to persons of feeble digestion than the use of tea.

Beef-tea, Salt, and Sugar.—We shall see presently that both beef-tea and salt exercise a considerable effect on peptic digestion; it was therefore desirable to test their influence on salivary digestion. I found that neither beef-tea, nor salt, nor sugar, in any such proportions as they were likely to be used dietetically, had any effect on salivary action. Strong solutions of salt and sugar did not hinder, and very weak ones did not appreciably assist.

Such are the facts relating to salivary digestion revealed by experiment. I have indicated, in going along, the lessons to be learned from them. You will observe that none of the agents tried lent any assistance to the action of the ferment. Those that were not indifferent acted adversely. Tea and wines retarded the most powerfully. The distilled spirits, coffee and cocoa, as used dietetically, may be pronounced to be indifferent. The mitigating effects of bicarbonate of soda on tea, and of the commercial table-waters on wines, appear to be well worth bearing in mind.

III.

EFFECT OF FOOD-ACCESSORIES ON PEPTIC DIGESTION.

(*Third Lecture of the Owens College Course.*)

SUMMARY:—Method of experimentation—Effect of varying quantities of hydrochloric acid—and of pepsin—Effect of alcohol and the distilled spirits—Port and sherry—Hock, claret, and champagne—Malt liquors—Effervescent table-waters—Tea and coffee—Beef-tea and whey—Sugar, salt, glycerine, and fruit-juices.

THE full force of the accessory articles of food falls upon gastric digestion. Both the food and the accessories used therewith pass almost unaltered into the stomach, and sojourn there together for some length of time. Experiments *in vitro* on gastric digestion do not assimilate so closely to the natural function as is the case with experiments on salivary digestion. For, as digestion proceeds in the stomach, the conditions gradually vary and change; the acidity tends to increase in degree, the amount of pepsin also probably increases; the products of digestion are in part absorbed as the process goes on; there is also a rapid absorption in the stomach of saline matters and of such bodies as alcohol and ethereal compounds. With all this there is a much more perfect stirring up or churning of the gastric contents than can be effectuated in a glass tube or beaker. The results of experiment must therefore be interpreted with a certain allowance for these differences of conditions.

Method of Experimentation.—Seeing that the chief work of the stomach is to get the solid proteids of the food into solution, or into a homogeneous magma or chyme, the most suitable objects for experiment on gastric digestion are the various meat and fish muscle-fibre, boiled white-of-egg, and bread. Meat-fibre was prepared by mincing lean beef, carefully freed from fat, and boiling it for fifteen minutes in two successive waters. The dry and hard-looking residual fibre, after copious washing with cold water and pressing with a cloth, was then pounded in a mortar, and spread out to dry at 100° C. When thoroughly dried it was reduced to a powder and passed through a fine wire sieve. In this way a dry powder was obtained of very uniform character. Fish-fibre, from the cod, was prepared in exactly the same way, and yielded an admirable material for experiments on digestion. White-of-egg was prepared by peeling off the white of hard-boiled eggs and then pressing the material through a fine wire sieve. By this device, long, thin, uniform cylinders of egg-albumen were obtained, very well adapted for the purpose in hand. Bread was prepared simply by drying completely at 100° C. and then reducing to a fine powder and passing through a sieve.

Most of the experiments were repeated with egg-albumen, beef-fibre and fish-fibre, but the larger number of trials were made with the beef-fibre; and in the tables which follow the results with beef-fibre are almost the only ones recorded; for it was found that no essential differences showed themselves in the effect of the several food-accessories on the digestion of these three preparations.

The general plan of the experiments was the following. Four or five large glass tubes, *a*, *b*, *c*, *d*, and *e*, were each charged with two grams of dry meat- or fish-fibre (or ten grams of moist egg-albumen). 100 cubic centimeters of water, acidulated with hydrochloric acid to 0·15 or 0·2 per cent. HCl, were then added to each tube. The tubes were then set upright in a pan of warm water and maintained at blood heat. Tube *a* was always the control tube, or 'normal' tube, and contained nothing but the material operated on, acidulated water, and pepsin. The remaining tubes, *b*, *c*, *d*, and *e*, contained varying quantities of the liquid or substance the effect of which it was wished to test. This was always included in the dilution water—so that the digesting mixture always amounted to 100 cubic centimeters. When the meat or fish-fibre had fully swelled out in the acid medium—that is to say, in about twenty minutes—there were added to each tube 2 cubic centimeters of an active glycerine-extract of pepsin. The tubes were frequently and equally agitated as digestion proceeded. At the end of about thirty minutes, under these conditions, digestion was usually concluded in the control tube (tube *a*)—that is to say, nearly all the meat- or fish-fibre (or white-of-egg) had passed into solution. It could also be seen, by the depth and density of the undissolved residue in the other tubes, how digestion was going on in them. In the course of an hour, or two, or three, a fair judgment could be formed of the relative progress or speed of digestion in all the tubes. In recording the results the time of completed digestion in the control tube (or 'normal') was always taken as 100 minutes, though the real time was often only about 30 minutes. This was done partly to facilitate comparison of the results in the several tubes, and partly in order to approximate more nearly to the usual duration of digestion in the living stomach. In most of the tables which follow, the results recorded are not the results of single experiments, but the mean of several. They must accordingly be regarded not as precise, but as approximative, results.

For purposes which will appear later on, it was considered desirable, in the first instance, to ascertain the effect on the speed of digestion of varying quantities of hydrochloric acid—and of varying quantities of pepsin. The results of experiments on these points are recorded in Tables VI. and VII.

TABLE VI.—*Showing the effect of varying quantities of Hydrochloric Acid on the Speed of Peptic Digestion.*

2 grams beef-fibre + 1 c.c. glycerine-extract of pepsin + varying proportions of hydrochloric acid + water to 100 c.c.

Proportion of dry HCl in the Digesting Mixture	Time in which Digestion was completed
0·05 per cent.	500 minutes—almost no digestion
0·08 ,,	200 ,,
0·1 ,,	130 ,,
0·15 ,,	115 ,,
0·2 ,,	100 ,,
0·3 ,,	115 ,,
0·4 ,,	160 ,,
0·6 ,,	350 ,, embarrassed

You will observe that the highest speed of digestion was obtained with a proportion of acid amounting to 0·2 per cent. HCl. This accords with the results obtained long ago by other observers. There is, however, not much difference between any proportions of acid varying from 0·1 per cent. HCl to 0·3 per cent. HCl; but above and below these proportions of acid the speed of digestion rapidly declines. With a proportion below 0·08 per cent. HCl, or a proportion above 0·4 per cent. HCl, the time in which digestion is completed is more than trebled.

With varying quantities of pepsin and constant quantities of acid the relations are quite different, as the following table shows.

TABLE VII.—*Showing the effect of varying quantities of Pepsin on the Speed of Peptic Digestion.*

2 grams of dried fish-fibre + 0·15 per cent. HCl + varying quantities of glycerine-extract of pepsin + water to 100 c.c.

Proportion of Solution of Pepsin in the Digesting Mixture	Time in which Digestion was completed
0·125 per cent.	300 minutes
0·25 "	260 "
0·5 "	200 "
1· "	140 "
2· "	100 "

It is seen that the speed of digestion is roughly proportionate to the amount of pepsin in the digesting mixture. The more pepsin, the greater is the speed of digestion; and the less pepsin, the slower is the speed of digestion—without any limit on either side. And we should probably see, as I formerly observed with diastase and starch digestion,[1] that, if it were possible to arrange the experiment so as to eliminate all interfering conditions, the speed of peptic digestion would be found to be exactly proportional to the quantity of pepsin contained in the digesting mixture.

The observations of Richet[2] indicate that the degree of acidity of the contents of the stomach during digestion, although it varies through a considerable range, has a marked tendency to maintain a certain normal average (which he fixed at about 0·17 per cent. HCl); and that if either acid or alkali be added to the digesting mass the mean is presently restored automatically—the stomach in the former case ceasing to secrete acid, and in the latter case secreting an increased quantity of acid.

I now proceed to lay before you the results of the experiments made to test the effect of the various food-accessories on the speed of peptic digestion—and first with regard to alcohol and the various alcoholic beverages.

---

[1] See p. 70.

[2] *Du Suc Gastrique*, Paris, 1878.

Proof Spirit, Brandy, Whisky, and Gin.—The results are thrown together into a single column, because the ardent spirits were found to affect peptic digestion simply in proportion to the quantity of alcohol contained in them.

TABLE VIII.—*Shows the effect of Proof Spirit, together with Brandy, Whisky, and Gin, on Peptic Digestion.*

2 grams of beef-fibre + 0·15 per cent. HCl + 1 c.c. glycerine-extract of pepsin + varying proportions of proof spirit, brandy, whisky, or gin + water to 100 c.c.

Proportion of Proof Spirit, Brandy, Whisky, or Gin contained in the Digesting Mixture	Time in which Digestion was completed (Normal, 100 minutes)
5 per cent.	100 minutes
10 "	115 "
20 "	135 "
30 "	180 "
40 "	300 " embarrassed
50 "	almost no digestion

It is quite surprising to observe how slight the effect of alcohol is on the chemical acts of digestion. Under 10 per cent. of proof spirit there was no appreciable retardation. With 10 per cent. retardation was only barely detectable. With 20 per cent. there was quite distinct, but still only a slight, retardation. Above this point, however, the inhibitory effect of alcohol increased rapidly—it was considerable with 30 per cent. of proof spirit—with 40 per cent. digestion was evidently embarrassed, and with 50 per cent. the ferment was almost paralysed. Considering the quantity of brandy, whisky, or gin commonly used dietetically with meals, it is evident that the amount is not sufficient to appreciably retard the speed of gastric digestion. For if the digesting mass in the stomach be estimated at 2 lbs., a wine-glass (2 oz.) of brandy or whisky added thereto would only equal 5 per cent. of proof spirit, and this, as the table shows, is too small a proportion to hamper digestion. Even double this amount would scarcely have an appreciable effect. These spirits therefore impede digestion only when taken immoderately, and in intoxicating quantities. Moreover, alcohol is rapidly absorbed by the coats of the stomach, and its proportion in the digesting mass would be speedily reduced. These experiments therefore indicate that ardent spirits, as usually employed dietetically by temperate persons, act as pure stimulants to gastric digestion, causing an increased flow of gastric juice,[1] and stimulating the muscular contractions of the viscus, and so accelerating the speed of the digestive process in the stomach.

The less concentrated kinds of alcoholic beverages, wine and beers, have an effect on peptic action which differs importantly from that of the distilled spirits. Their inhibitory influence is greatly out of proportion to the dosage of alcohol contained in them. It is desirable to distinguish between the effects of the stronger wines (port and sherry), and of the lighter wines (clarets, hocks, and champagnes), and of malt liquors.

Sherry and Port Wines.—The sherry used was a full-bodied mature wine of the dessert class. The results were controlled by experiments with a light dinner sherry, and no great difference was found between them. The port used was over thirty years old, well matured and of a fine but light quality.

---

[1] We may assume that alcohol would act in this respect in the same way as it acts on the salivary secretion.

TABLE IX.—*Showing the effect of Sherry and Port on Peptic Digestion.*

2 grams of beef-fibre+0·15 per cent. HCl+1 c.c. glycerine-extract of pepsin +varying quantities of sherry and port+water to 100 c.c.

Proportion of Sherry or Port contained in the Digesting Mixture	Time in which Digestion was completed (Normal, 100 minutes)	
	Sherry	Port
5 per cent. . . .	115 minutes	100 minutes
10 „ . . .	150 „	115 „
15 „ . . .	200 „	150 „
20 „ . . .	300 „ embarsd.	180 „
30 „ . . .	almost no digestion	200 „
40 „ . . .	—	embarrassed

It is evident that the retarding effects of sherry and port considerably exceed what is due to the alcohol contained in them. The table shows that when the digesting mixture contained 40 per cent. of either wine the action of the ferment was almost brought to a standstill. These wines are estimated to contain about 20 per cent. of absolute alcohol (or 40 per cent. of proof spirit); therefore 40 per cent. of these wines is only equivalent in alcoholic strength to 16 per cent. of proof spirit—and this proportion of alcohol, as may be seen by Table VIII., retards digestion only slightly. Even in the proportion of 20 per cent., sherry trebled the time in which digestion was completed. There must therefore be in these wines some retarding agent besides alcohol. I shall return to this subject later on.

As used dietetically, sherry must figure as having frequently an important retarding effect on peptic digestion. This wine is used with dinner by some persons very freely. Half-a-pint of sherry is no unusual allowance; and this, in a total gastric charge of two pounds, amounts to about 25 per cent., which the table shows to be a highly inhibitory proportion. In the more common practice of taking two or three wine-glasses of sherry with dinner we see probably a double action—a stimulating action on the secretion of gastric juice, and on the muscular contractions of the stomach, and a slight retarding effect on the speed of the chemical process, especially in its early stages. In smaller proportions, a wine-glass or so, sherry would act as a pure stimulant to digestion. In connection with the dietetic use of sherry, it should be further remembered that it exercises a strong inhibitory effect on the salivary digestion of bread and other farinaceous articles.

Hock, Claret, and Champagne.—The hock and claret (Bordeaux) used were of medium quality; the champagne was Moët & Chandon's 'extra superior.'

TABLE X.—*Shows the effect of Hock, Claret, and Champagne on Peptic Digestion.*

2 grams of dried beef-fibre+0·15 per cent. HCl+1 c.c. glycerine-extract of pepsin+varying proportions of hock, claret, or champagne+water to 100 c.c.

Proportion of Hock, Claret or Champagne in the Digesting Mixture	Time in which Digestion was completed (Normal, 100 minutes)		
	Hock	Claret	Champagne
10 per cent. . .	100 minutes	100 minutes	90 minutes
20 " . .	115 "	140 "	100 "
40 " . .	150 "	180 "	130 "
60 " . .	embarrassed	embarrassed	180 "

We observe again that the retarding effect of these wines is out of proportion to the alcohol contained in them. These wines are estimated to contain from 10 to 12 per cent. of absolute alcohol (20 to 24 per cent. of proof spirit), so that, however freely they might be used dietetically, the amount of alcohol so introduced, even if they were used up to 80 per cent. of the total contents of the stomach, would scarcely produce an appreciable effect on peptic action. We must, therefore, again here recognise the presence of some other retarding agent besides alcohol. The table shows that champagne has a markedly less retarding effect than hock and claret. Indeed, in the proportion of 10 per cent., champagne had a distinct, though slight, accelerating effect. This superiority of champagne is due probably, as we shall presently see reason to believe, to the mechanical effects of its effervescent qualities.

If we consider the copious proportions in which hock and claret are used dietetically, it becomes evident that their retarding effect on peptic digestion is often brought into play. A pint of claret or hock is a common allowance with dinner for robust eaters—and such a proportion, as the table shows, would not be without considerable effect. When French and Italian peasants use freely, as they do, a wine akin to claret with their meals, which are mainly composed of bread and other farinacea, the effect must be highly retarding on digestion.

On the other hand, the more sparing use of these wines, a glass or two, with dinner or luncheon would evidently not produce any appreciable retardation of peptic action, but would, like corresponding doses of sherry, act as pure stimulants. In both these instances, as in some others, it seems to be indicated that by adjusting the quantities we may elicit diverse effects. With large quantites we may obtain retardation, with small quantities we may obtain acceleration of gastric digestion.

Malt Liquors.—The malt liquors experimented on were bottled Burton ale, a light sparkling English table beer, and Lager beer.

TABLE XI.—*Shows the effect of Malt Liquors on Gastric Digestion.*

2 grams of dried beef-fibre + 0·15 HCl + 1 c.c. glycerine-extract of pepsin + varying quantities of malt liquors + water to 100 c.c.

Proportion of Malt Liquors contained in the Digesting Mixture	Time in which Digestion was completed (Normal, 100 minutes)		
	Burton ale	Light English table beer	Lager beer
10 per cent. . .	115 minutes	100 minutes	100 minutes
20 " . .	140 "	115 "	115 "
40 " . .	200 "	140 "	140 "
60 " . .	embarrassed	180 "	180 "

The retarding effect of malt liquors is (as is the case with wines) altogether out of proportion to their percentage of alcohol. These beverages contain only from 4 to 6 per cent. of alcohol (8 to 12 per cent. of proof spirit), so that the alcohol contained in them could scarcely ever, on its own account, produce any effect. Their retarding influence must, however, often come into operation. These beverages are used very freely with meals, and the digesting mass in the stomach must often contain them in the proportion of 50 or 60 or sometimes even 80 per cent. Such proportions would act as powerful retardants, especially on the digestion of bread and other articles of farinaceous food. In more moderate quantities—a tumbler or so—especially of the lighter beers, the effect would evidently be rather to promote than to retard gastric digestion. It was found experimentally that beer when 'well up' was distinctly more favourable to quick digestion than the same beer when 'flat.'

Effervescent Table Waters.—Simple carbonated water distinctly hastened peptic digestion; but the favourable effect was quite subordinate—and it was better brought out with proportions of 10, 20, and 40 per cent. than with larger proportions. I attributed the slight acceleration observed entirely to the mechanical operation of the escaping gas in causing an additional stirring up of the digesting mixture. The ordinary commercial effervescent table waters—soda- and potash-water, seltzer and Apollinaris waters—all contain, as before stated, a certain quantity of an alkaline carbonate. This would have necessarily a certain neutralising effect on the acid of the gastric juice. But I was surprised to find, even in a laboratory experiment—wherein, of course, there could not be, as would be the case in the living stomach, any compensating secretion of fresh acid—that these waters had, even in the proportion of 90 per cent., only a very slight and insignificant deterrent effect on peptic digestion. In smaller proportions their action was quite inappreciable. It may be inferred from these observations that the sparkling wines (as indeed was found experimentally to be the case with champagne) are less hindering to digestion than the still wines; and that, when used in moderate proportions, they may act, not only as stimulants to the secretion of gastric juice and to the muscular activity of the viscus, but may, at the same time, slightly accelerate the speed of the chemical process in the stomach.

Tea and Coffee.—The effect of these important beverages is of great interest, in view of their wide diffusion and copious use. A large number of observations were made with the object of testing their influence on peptic digestion. The mean results are indicated in the following table:—

TABLE XII.—*Shows the effects of Tea and Coffee on Gastric Digestion.*

2 grams of dried beef-fibre+0·15 HCl+1 c.c. glycerine-extract of pepsin +varying proportions of tea and coffee+water to 100 c.c.

Proportion of Tea or Coffee contained in the Digesting Mixture	Time in which digestion was completed (Normal, 100 minutes)		
	Tea—5 per cent. strength	Coffee—5 per cent. strength	Coffee—15 per cent. strength
10 per cent.	105 minutes	105 minutes	160 minutes
20 ,,	140 ,,	140 ,,	embarrassed
40 ,,	180 ,,	180 ,,	almost no action
60 ,,	embarrassed	embarrassed	—

It is seen that both tea and coffee exercise a powerful retarding effect on peptic digestion. With infusions of equal strength there was no appreciable difference between the two beverages; but inasmuch as coffee is usually made of greater strength than tea, its effect, as dietetically used, is more potent. Cocoa was found, with infusions of equal strength, to possess nearly as much retarding effect as tea or coffee; but as it is usually made with a strength of only about 2 per cent., its inhibitory effect scarcely comes into play in the customary use of this beverage. Strong coffee, the 'café noir' of France, is seen to have a very powerful inhibitory effect. Even so small a proportion as 10 per cent. of this strong coffee in the digesting mixture abated the speed of digestion very considerably, and with 20 per cent. digestion was greatly embarrassed. Considering the copious proportions in which we use tea and coffee with our meals, it is obvious that the retarding effect of these beverages is commonly brought into operation in gastric digestion. I could not detect any appreciable difference between the effect of tea infused for 2 or 3 minutes and tea infused for 15 or 30 minutes. If you wish to minimise the retarding effects of tea, in persons of weak digestion, you should give instructions either that the beverage be made weak or that it be used in sparing quantities.[1]

The effect of tea on gastric digestion is enhanced, in regard to bread and other farinaceous articles, by its powerful inhibitory action on salivary digestion; so that, speaking of these two phases of digestion together, tea must rank much higher as a retarding agent than coffee and cocoa. In the case of alcoholic beverages, their stimulating influence on secretion, and on the muscular activity of the stomach, operates as a partial set-off against their retarding effect on the chemical process of peptic digestion; but in the case of tea and coffee there is not, so far as is known, a corresponding compensation. Tea and coffee are probably pure retarders of the digestive process in the stomach; and the question will presently arise as to whether this is an evil or a good.

Beef-tea and Whey.—Beef-tea may be regarded as the representative type of the various soups and broths which are so largely used as accessories to the more solid ingredients of our meals. And the unexpected effects of beef-tea on peptic digestion led to an examination of the effects of whey, and of infusions or decoctions of other articles of food—bread and fruit, and also of fruit juices. The results obtained with beef-tea and whey are chronicled in the following table. The beef-tea was made by gently boiling or simmering lean minced beef with an equal weight of water for thirty minutes, and filtering. The whey was made by coagulating warm milk with the peptic extract and then straining and filtering.

---

[1] A good deal has been said of the injurious effects on gastric digestion of the tannin contained in tea. I question whether the statements made with reference to this matter are worthy of attention. It has been alleged that meat-fibre is hardened by tea, and that the coats of the stomach are liable to be injured by this beverage. These views are entirely theoretical. Leather is no doubt a very tough, indigestible substance, but meat-fibre is not gelatine, and the coats of the living stomach are not dead membrane. Meat-fibre does not, as a matter of fact, harden in tea; on the contrary, it swells nearly as freely in acidulated tea, of medium strength, as in simple acidulated water. And the same is true of a half per cent. solution of pure tannin. The effect of tannin on peptic action is comparatively slight; and its presence in tea only partially accounts for the inhibitory power of tea on the digestion of proteids in the stomach. The acid reaction of the gastric contents importantly modifies the reaction of tannin on albuminoid solutions, and largely obviates the precipitation of proteids which is occasioned by it in neutral media.

TABLE XIII.—*Shows the effect of Beeef-tea and Whey on Peptic Digestion.*

2 grams of dried beef-fibre + 0·15 HCl + 1 c.c. glycerine-extract of pepsin + varying quantities of beef-tea or whey + water to 100 c.c.

Proportion of Beef-tea or Whey in the Digesting Mixture	Time in which Digestion was completed (Normal, 100 minutes)	
	Beef-tea	Whey
10 per cent. . .	115 minutes	105 minutes
20 " . .	140 "	130 "
40 " . .	embarrassed	150 "
60 " . .	almost no digestion	embarrassed

It is seen from the table that beef-tea has a powerfully retarding effect on peptic digestion—about equal to that of a five-per-cent. tea. Whey retarded sensibly less—about equal to hock.

With the single and trifling exception of aerated (carbonated) water, I found that none of the various accessories which we use with food aided peptic digestion. The most favourable conditions for rapid digestion were obtained with hydrochloric acid, pepsin, and simple water. Even minimal quantities of alcohol, wines, tea, or coffee did not give the least assistance to the chemical process. Some of the substances tried were found to be indifferent; or their retarding effect was so slight that in the quantities in which they are generally used dietetically the retardation could not be regarded as having any practical importance. Among these were cane-sugar up to a proportion of 10 per cent., glycerine up to the same proportion, strong decoctions of bread, ripe apple, and pear, and the expressed juice of the grape and the orange. In regard to the two last, however, it was found that when their proportion in the digesting mixture amounted to 50 per cent. or over a very considerable retardation occurred: grape juice had a more potent effect than orange juice. So large a proportion as 50 per cent. of these juices could, however, only occur in the gastric contents when these fruits were taken immoderately, as sometimes happens with children.[1]

---

[1] Dr. W. J. Fraser has published, in vol. xviii. of the *Journal of Anatomy and Physiology*, a very interesting paper—based on a large number of elaborate experiments—dealing with the effects of tea, coffee, and cocoa on peptic digestion. The results obtained by Dr. Fraser coincided generally with those recorded above; he found that these beverages in nearly every instance retarded peptic digestion. The plan of the experiments differed so widely from that followed by myself that it was not found possible to bring the results of the two sets of experiments into useful comparison.

IV.

EFFECT OF FOOD-ACCESSORIES ON PEPTIC DIGESTION CONTINUED—THEIR EFFECT ON PANCREATIC DIGESTION.

(*Fourth Lecture of the Owens College Course.*)

SUMMARY:—Causes of the retarding effects of food-accessories on peptic digestion—In the cases of beef-tea and whey—Action of salts of the organic acids—and of chlorides of potassium and sodium—Effect of superacidulation and dialysis in removing the retarding effects of food-accessories—Retardation of peptic digestion probably beneficial in purpose—Argument on this question.

Effect of food-accessories on pancreatic digestion—On pancreatic diastase—On tryptic digestion.

THE general results of the experiments described in the preceding lecture appeared to me not a little remarkable. I was particularly surprised to find that beef-tea and whey, which, as meat-juice and milk, are common articles of food, and which are given to invalids, should rank with alcohol, wines, tea, and coffee—and even, in the case of beaf-tea, rank high—as retarders of peptic digestion. And nothing struck me more than the comparative feebleness of alcohol in this respect. Proof spirit, whisky, and brandy had no more retarding effect than so much beef-tea, and we have previously seen that alcohol is still more feeble as a retarder of salivary digestion.

What is the cause of these retarding effects? On inquiring into this question it was speedily seen that the cause was different in different cases. In the case of proof spirit the cause must, of course, be due directly to the alcohol contained in it; and the same is true of whisky, brandy, and gin, in regard to which it was found that their retarding effect was proportional to the quantity of alcohol they contained. But in regard to wines and malt liquors, their percentage of alcohol did not account for nearly their full effect; and with tea, coffee, beef-tea, and whey, alcohol had, of course, no part in the retarding effect produced by them. These latter are all highly complex fluids containing various ingredients of widely different nature. The wines, besides alcohol, contain ethereal compounds and saline and extractive matters; and malt liquors contain, in addition to a small dosage of alcohol, the extractive matters of hops, dextrines, and salines. Tea and coffee contain the alkaloid theine (or caffeine), an essential oil, salines, and a bitter principle. Tea contains a large percentage of tannin, and coffee a still larger percentage of caffeo-tannic acid. Beef-tea and whey are rich in organic salts and other saline matters, besides very complex extractives. It is not surprising, therefore, that inquiry into the causal agent of retardation should reveal profound differences in this respect.

I have by no means mastered this subject, but I have obtained a certain amount of light, which has both a positive and a negative bearing.

It will facilitate matters if I take first the cases of beef-tea and whey. I think I have made out in both these instances that their retarding effect on pepti digestion is due to the presence in them of salts of th organic acids and of neutral inorganic salts; namely, t the lactates and sarcolactates, and to the chlorides potassium and sodium which they contain.

It has been shown by Berthelot that salts of t organic acids are decomposed in the presence of the mineral acids, just as the carbonates are—with this difference only, that in the latter case the carbonic acid, being gaseous, escapes with effervescence, whereas in the former case the organic acids which are set free remain in the solution. Therefore, when lactate or tartrate of potash is mixed in solution with free hydrochloric acid, there is immediately formed chloride of potassium, and free lactic or tartaric acid. And this is exactly what occurs in the stomach with beef-tea and whey, for the hydrochloric acid of the gastric juice seizes on the alkaline bases of the lactates contained in these liquids, forming therewith chlorides of sodium and potassium, and setting free the organic acid; and although the acidity of the gastric contents is not thereby diminished, this acidity no longer consists of hydrochloric acid, but partly of that and partly of lactic acid: and if the quantity of beef-tea be considerable, all the hydrochloric acid may disappear, and only lactic acid be left free in the solution. The effect of this substitution is immense, for the organic acids have only a very feeble digestive power as compared with hydrochloric acid. On comparing experimentally lactic and tartaric acids with hydrochloric acid, I estimated that for equal saturating power the organic acids had not more than one-eighth or one-tenth of the digestive power of the mineral acid.

In order to test the actual effect of an organic salt on peptic digestion I made some observations with the neutral tartrate of potash. Varying quantities of this salt were added to the usual digesting mixture. The following table exhibits the results obtained:—

TABLE XIV.—*Showing the effects of Salts of the Organic Acids on Peptic Digestion—Neutral Tartrate of Potash.*

10 grams moist egg-albumen + 0·2 HCl + 2 c.c. glycerine-extract of pepsin + varying quantities of neutral tartrate of potash + water to 100 c.c.

Proportion of Tartrate of Potash in the Digesting Mixture	Time in which Digestion was completed (Normal, 100 minutes)
0·05 per cent. = 1 in 2,000 . .	115 minutes
0·125 ,, = 1 in 800 . .	160 ,,
0·25 ,, = 1 in 400 . .	embarrassed
0·5 ,, = 1 in 200 . .	almost no digestion

It is seen from the table that even so small a proportion of the tartrate as 1 in 2,000 retards digestion appreciably, and that 1 in 800 retards it considerably. To obtain an idea of the effect of this in the living stomach, let us suppose that the total gastric contents during digestion amounted to two pounds (14,000 grains), then so small a quantity as seven grains of the tartrate of potash would slightly prolong digestion, and eighteen grains would retard it considerably.

But the mere substitution of the organic for the mineral acid is not all—the presence of the newly formed chlorides in the digesting mixture is an additional cause of embarrassment to the digestive process. The annexed table exhibits the effects of the chlorides of sodium and potassium on peptic digestion.

TABLE XV.—*Showing the effects of Sodium and Potassium Chlorides on Peptic Digestion.*

10 grams moist egg-albumen + 0·2 HCl + 2 c.c. glycerine-extract of pepsin + varying quantities of sodium and potassium chlorides + water to 100 c.c.

Proportion of NaCl or KCl in the Digesting Mixture	Time in which Digestion was completed (Normal, 100 minutes)	
	Sodium Chloride	Potassium Chloride
0·1 per cent. = 1 in 1,000	115 minutes	108 minutes
0·25 ,, = 1 in 400	150 ,,	130 ,,
0·5 ,, = 1 in 200	embarrassed	150 ,,
1· ,, = 1 in 100	almost no digestion	embarrassed

The table shows that sodium chloride has a very considerable power of retarding peptic action. Even in the proportion of 1 in 1,000 it has an appreciable effect; and with 0·5 per cent. (or 1 in 200) the effect is so great as almost to bring the process to a standstill; the potassium salt has very distinctly less retarding effect, as the table indicates, than the sodium salt.[1]

These observations yield presumptive evidence that the lactates and neutral mineral salts known to exist in beef-tea are the real retarding agents of that liquid, and that probably kindred salts contained in whey, beer, and wines may account, at least in part, for the retarding effects of these beverages.

Now, if this explanation be correct, we ought to find that by increasing the hydrochloric acid in a digesting mixture containing beef-tea the retarding effect is mitigated. For if the lactates of beef-tea cause occultation of a portion of the free mineral acid, and thereby retard the speed of digestion, we should expect to find that the addition of more of the mineral acid, so as to compensate for this loss, would partly obviate the retarding effect; and this is precisely what occurred on experiment. The effect of *superacidulation* was tested not only with beef-tea, but also with whey, coffee, tea, wines, and malt liquors. The results obtained, however, only fully answered expectation in the cases of beef-tea and whey.

---

[1] The powerful inhibitory effect of sodium chloride on peptic digestion has probably some bearing on the old debated question of why the stomach does not digest itself. The blood-serum contains just 0·5 per cent. of sodium chloride, and this proportion is seen by the table to inhibit peptic digestion. No doubt, as Dr. Pavy pointed out, the principal obstacle to the self-digestion of the stomach during life is the alkaline reaction of the blood-serum; but the presence in it of the sodium chloride constitutes an additional and very interesting security against such a disaster.

In regard to the other beverages named the results were either *nil* or very slight. The observations tabulated in Table VI., page 130, indicate that the rate of digestion of beef-fibre is sensibly the same with an acidulation of 0·15 per cent. HCl and with an acidulation of 0·3 per cent. HCl. Accordingly comparison was made with these two grades of acidulation in digesting mixtures containing an inhibitory proportion (that is to say, a proportion which would approximately treble the normal time of digestion) of beef-tea, whey, coffee, tea, wines, or malt liquors. The results obtained are chronicled in the following table:—

TABLE XVI.—*Showing the effect of Superacidulation on Digesting Mixtures containing Inhibitory Quantities of various Beverages.*

2 grams of dried beef-fibre + 2 c.c. peptic-extract + inhibitory quantities of beef-tea, whey, tea, coffee, wine, or malt liquor + water to 100 c.c.

Addition to the Digesting Mixture		Time in which Digestion was completed (Normal, 100 minutes)	
		0·15 per cent. HCl	0·3 per cent. HCl
Beef-tea	40 per cent.	300 minutes	120 minutes
Whey	50 ,,	300 ,,	130 ,,
Coffee	50 ,,	300 ,,	200 ,,
Tea	50 ,,	300 ,,	240 ,,
Claret	50 ,,	300 ,,	300 ,,
Hock	50 ,,	300 ,,	300 ,,
Burton ale	50 ,,	300 ,,	300 ,,
Sherry	20 ,,	300 ,,	330 ,,
Port	30 ,,	300 ,,	330 ,,

It is seen that with beef-tea superacidulation acted powerfully in obviating the retarding effect, in fact almost nullifying it altogether. With whey the increased acidity also acted powerfully in the same direction—not nearly so much, but still considerably, with coffee—much less with tea—and not at all with the lighter wines and Burton ale. With sherry and port superacidulation distinctly intensified the inhibitory effect of these beverages.[1]

The conclusions were therefore arrived at that the inhibitory effects of beef-tea and whey were largely due to the salts of the organic acids contained in them, that the same explanation applied only partially to the effects of coffee, and still less with regard to tea. In the case of wines and malt liquors, it was evident that their inhibitory effects must be otherwise accounted for.

Further light on the retarding effects of these several food-accessories was sought by subjecting them to dialysis, whereby a rude and imperfect but suggestive idea could be obtained of the effect on them of absorption through the walls of the stomach. In each case 100 cubic centimeters of the liquid to be tested were dialysed for six hours into 3,000 cubic centimeters of water; and the retarding effect of the dialysed product was compared with that of its undialysed counterpart. The results are recorded in the following table:—

TABLE XVII.—*Showing the effects of Dialysis.*[2]

2 grams dried beef-fibre + 0·15 HCl + 2 c.c. peptic extract + varying quantities of dialysed and undialysed beef-tea, whey, coffee, tea, light wines, or Burton ale + water to 100 c.c.

Addition to the Digesting Mixture	Time in which Digestion was completed (Normal, 100 minutes)	
	Undialysed	Dialysed for 6 hours
Beef-tea 40 per cent.	300 minutes	120 minutes
Whey 50 ,,	300 ,,	135 ,,
Coffee 50 ,,	300 ,,	210 ,,
Tea 50 ,,	300 ,,	240 ,,
Claret 50 ,,	300 ,,	210 ,,
Hock 50 ,,	300 ,,	210 ,,
Burton ale 50 ,,	300 ,,	195 ,,

---

[1] I take this to be due to the large proportion of alcohol contained in sherry and port; for I found that with proof spirit also superacidulation acted adversely on the speed of peptic digestion.

[2] The increase of the product in the dialyser varied a good deal. In

The results of dialysis, as shown in the above table, yield the same indications as superacidulation, and lead to the conclusion that in regard to beef-tea and whey the retarding agents are the crystalloids contained in these liquids, and which dialyse with rapidity. Coffee and ale were also considerably affected by dialysis, but tea and the light wines were only slightly affected by dialysis for six hours. I found that by dialysis for twenty-four hours the retarding power of all these beverages was almost entirely removed.

From these observations on superacidulation and dialysis it was inferred that with beef-tea and whey the saline matters contained in them are wholly answerable for their retarding effect on peptic digestion. With regard to coffee, the retarding effect is partially due to saline matters, perhaps chiefly to the caffeo-tannate of potash contained in that beverage. In the case of ale it would also seem that the saline ingredients contained therein account for a considerable portion of its retarding effect; and it would further appear, from a comparison of the effects of superacidulation on the one hand and dialysis on the other, that the retarding salines of ale are not salts of the organic acids, but neutral mineral salts—probably chlorides and phosphates of potash and soda.

In the cases of tea and coffee there arose the question whether the alkaloid, theine or caffeine, contained in these beverages contributed anything to their retarding effect on peptic digestion. Direct experiments gave a negative answer to this question. It was found that

---

the case of beef-tea, whey, the wines, and beer the increase amounted to about 10 per cent.; in the case of coffee to 4 per cent.; and in the case of tea to only 1 per cent. Allowance was made in the experiments for these differences.

citrate of caffeine, up to a proportion of 1 per cent. in the digesting mixture, had no appreciable effect—and this is a far larger proportion of the alkaloid than ever gets into solution in our ordinary infusions. Neither has the volatile oil contained in tea and coffee any effect. Tea and coffee which had been heated on a plate at 100° C. for a period of four hours—whereby both the volatile oil and the alkaloid would be driven off—yielded infusions which had not appreciably lost any of their retarding effects. The tannin of tea accounts for a portion of the retarding power of this beverage, but only for a portion. I found experimentally that the tannin contained in tea accounted for about one-half of the retarding effect of that beverage on peptic digestion.

With regard to wines, I am unable to account for their retarding effect on peptic digestion. Neither superacidulation nor dialysis gave support to the idea that it was due to their saline ingredients. The retardation caused by these beverages was wholly out of proportion to the alcohol contained in them. In the case of sherry it was found that when this wine was briskly boiled for five minutes, and the loss by evaporation afterwards made up by the addition of water, its inhibitory effect was lessened by fully one-half. This showed that the high retarding power of sherry was largely due to its volatile constituents.

Speaking generally, we may infer that the retarding effects of beef-tea and whey are due to conditions which are easily obviated in the living stomach—either through the rapid absorption of their saline ingredients by the gastric capillaries, or through an increased secretion of gastric acid. But in regard to coffee, tea, the wines, and malt liquors, their retarding agency would appear to be less easily removable, and would therefore exercise a more persistent influence on gastric digestion. The retarding power of beef-tea and whey is, however, worth bearing in mind: it accounts perhaps for the difficulty and discomfort which some persons notoriously experience in the digestion of soups and milk; and points to the desirability of restricting the amount of these fluids in persons of weak digestion. The practice of taking soup at the beginning of dinner is so widespread that it must be credited with some beneficial purpose. The object of the practice probably is to awaken the stomach to its work.[1] Taken on an empty stomach, the salines of the soup would be rapidly absorbed, and in passing through the coats of the stomach they would provoke both the glandular and the muscular activity of the organ. Taken in due quantity this would probably be the only effect, but taken in large quantity soup would undoubtedly display its retarding power on the chemical act of peptic digestion; it should therefore be partaken of sparingly by persons of feeble digestion. This rule, I apprehend, accords perfectly with common experience.

I shall have occasion to explain further on why beef-tea and milk, notwithstanding their retarding effects on the chemistry of gastric digestion, are nevertheless often suitable aliments for sick persons.

I come now to a curious and interesting question. What is the meaning of all this retarding effect? Why should the practice be almost universal among civilised races of taking with their meals beverages which retard digestion? And, considering the copious libations[2] of tea, coffee, beer, or light wines which healthy persons associate with their meals, it is quite evident that an important retardation of gastric digestion is thereby frequently produced.

---

[1] *See* also remarks on peptogens, p. 54.

[2] This, however, only applies to persons in health. These agents figure quite differently in the dietetic habits of invalids. They are either altogether omitted from their dietary or used sparingly, or very diluted.

Is this retardation wholly, or even at all, evil? Do we healthy people take tea, coffee, wines, or beer with our meals for some collateral good, and in spite of their untoward retarding effect on the chemistry of digestion, or is there really some good in this retardation itself? and do we unconsciously use these beverages partly for this very purpose of abating the speed of gastric action?

It requires perhaps some courage to set forth and to defend a proposition apparently so paradoxical as that men take these beverages in part with the unconscious purpose of retarding their digestion. This is, however, what I propose doing, and I am countenanced in this speculative course by some words of Darwin. 'False facts,' he says, 'are highly injurious to the progress of science, because they often endure long; but false views, if supported by some evidence, do little harm, because everyone takes a salutary pleasure in proving their falseness; and when this is done one path of error is closed and the true path is often at the same time opened.'[1] The view I am about to suggest concerning digestive retardation may be true or false, and must submit to the test of criticism; but the facts indicated by the experiments stand equally fast whether that view prove true or false.

It does not really require much ingenuity to show cause why retardation of gastric digestion may not be regarded in the healthy and strong as having a beneficial purpose.

We must bear in mind that among civilised races the preparation of food for the table is carried to a high degree. The cereal grains which are employed to make bread are first finely ground and sifted from the bran by the miller; the flour is then subjected, with the aid of moisture and artificial heat, to a cooking process; the meats and fish we eat are boiled or roasted; the vegetables we use are carefully deprived of their coarser parts, and then are boiled: all this preliminary preparation and cooking renders our food highly digestible, and easy of attack by the digestive juices. But this is not, I apprehend, the sole object in view. The preliminary preparation and cooking not only renders our food more digestible, but makes it also more capable of being thoroughly exhausted of its nutritive qualities. These two objects are not quite the same. Even as it is, and with all this careful preparation, some waste occurs; and the fæces always contain considerable remnants of undigested food. But it is obvious that, if food be rendered too easy of digestion, there arises a risk that the meal will pass too quickly, and wastefully, into the blood, and on through the tissues into the excretory organs, and so out of the body, before it has been made fully and economically available for the sustenance of the slow nutritive processes. Moreover, a sudden irruption into the blood of large quantities of newly digested aliment would tend to disturb the chemical equilibrium of that fluid, and so interfere with the tranquil performance of its functions. It would also tend to produce hepatic and other congestions, to the general disadvantage and discomfort of the economy. A too rapid digestion and absorption of food may be compared to feeding a fire with straw instead of with slower burning coal. In the former case it would be necessary to feed often and often, and the process would be wasteful of the fuel; for the short-lived blaze would carry most of the heat up the chimney. To burn fuel economically, and to utilise the heat to the utmost, the fire must be damped down, so as to ensure slow as well as complete combustion. So with human digestion, our highly prepared and highly cooked food requires, in the healthy and vigorous, that the digestive fires should be damped down in order to ensure the economical use of food.

---

[1] *Descent of Man*, chap. xxi.

In the plan of the dietary of the civilised races, arrived at slowly as the result of an immense experience, we seem therefore to detect two apparently contradictory aims—namely, on the one hand, to render food by preparation and cooking as digestible as possible; and, on the other hand, to control the rate of digestion by the use of certain accessory articles with food. In reality these objects are not contradictory but co-operative to a beneficial end. For, to express the problem in another way, it may be said that we render food by preparation as capable as possible of being completely exhausted of its nutrient properties; and, on the other hand, to prevent this nutrient matter from being wastefully hurried through the body we make use of agents which abate the speed of digestion.[1] This combination of appliances renders our plan of feeding more elastic, more adaptable to variety of individual health and constitution, and to variety of external conditions.[2]

During the early periods of life retardation of digestion is less required than in the adult state, because the growing organism can more fully utilise, in the work of the building up of the framework, any excess of food which is poured into the blood. Accordingly we observe that retarding agents (tea, coffee, and alcoholic beverages) are not used at all, or only used sparingly, by infants and children.

---

[1] A slow digestion is quite a different thing from an imperfect digestion; indeed, it has seemed to me that dyspeptics sometimes suffer not from a too slow but from a too hurried digestion.

[2] The practice of the Irish peasant to underboil his potato, so as to leave a 'stone,' as it is said, in the middle of it; and the practice of the Scotch peasant to undercook his oatmeal—for he makes his 'brose' not by boiling, but simply by pouring boiling water on the meal—both these practices seem designed to check the speed of digestion, and thereby to enable the meal to 'stay' the stomach for a longer period.

If this view of digestive retardation in the stomach be well founded, the stomach becomes in some degree a storage organ for food—like the crop of birds, the paunch of ruminants, the dilatable cheeks of monkeys, and the pouch of the pelican.

Use of Salt.—Why do we use so much salt with our food? Animals in a state of nature require none. They find (with most rare exceptions) all the salt they require in their natural food; but cooks are always adding salt in their culinary operations, and we have it nearly always on our plates. This habit is probably dependent on the elaborate preparation and cooking to which we subject our food. In the preparation of flour the wheat is robbed of its outer coating, or bran, which contains the larger part of the saline matters of the grain. Potatoes and green vegetables are boiled in large quantities of water, and are therefore deprived of their saline ingredients. Meat and fish are boiled or roasted, and thereby lose some of their mineral constituents. Salt must therefore be supplied artificially to make up the defect, and to restore to the food so treated that sapidity and salinity of which it has in part been deprived. It has been remarked that tribes and races which subsist chiefly on a vegetable diet have more need of salt than meat-eating communities.

EFFECT OF FOOD-ACCESSORIES ON PANCREATIC DIGESTION.

The effects of the food-accessories on pancreatic digestion must obviously be less important, and also more difficult to estimate, than in the case of salivary and peptic digestion. These accessories undergo changes in the stomach; alcohol and saline matters are largely absorbed in that viscus, so that the beverages containing them are considerably modified by the time they reach the duodenum. And not only are the accessories altered by their sojourn in the stomach, but the articles of food are also profoundly altered. Digestion is already half accomplished, the solid proteids are partly reduced to a state of solution, and the entire gastric mass is converted into a more or less homogeneous chyme. When this enters the duodenum it encounters the alkaline secretions of the liver and pancreas. A large part of the dissolved matter is reprecipitated by the neutralisation which then occurs, and the whole digesting mixture becomes alkaline in reaction. The digestion of starchy matters, suspended in the stomach, is now actively resumed; the digestion of the undissolved proteid matters which came through the pylorus, and of the neutralisation precipitate, recommences and proceeds to its final termination.

Pancreatic digestion appeared in my experiments, except in the cases of milk and farinaceous matters, to be essentially slower than gastric digestion. On meat- and fish-fibre and on egg-albumen pancreatic extract acted with extreme slowness, but on milk the action was extremely rapid—so likewise on bread. The agency of the stomach seems especially necessary for the digestion of all kinds of meat.

In considering the effect of food-accessories on pancreatic digestion we have to distinguish between the diastasic and tryptic action of pancreatic juice.

Effect of Food-accessories on Pancreatic Diastase.—The action of alcohol on the pancreatic digestion of starch was found to be identical with its effect on salivary digestion (see p. 116). In regard to wines and beer, it was found, as explained in a preceding lecture, that their inhibitory influence on the action of salivary diastase was entirely due to the acidity of these beverages. The same is the case with their action on pancreatic diastase—and as this acidity is removed by the alkaline juices of the duodenum, these beverages are without any effect on the pancreatic digestion of starch. In the case of tea the reaction of the medium also governs the result. For, although tea is highly inhibitory of pancreatic, as of salivary, amylolysis, this inhibitory action is removed (or almost removed) by changing the reaction from neutral or faintly acid to alkaline. When therefore tea passes into the alkaline atmosphere of the duodenum, it ceases to have any effect on the pancreatic digestion of starch, or at least any effect of practical significance.

Effect of Food-accessories on Tryptic Digestion.—I tested experimentally the effect on tryptic digestion of milk, of alcohol, and of tea and coffee. Alcohol had a distinctly retarding influence when its proportion in the digesting mixture rose to 5 per cent. of absolute alcohol (10 per cent. of proof spirit), but the effect was comparatively slight. The digestion of milk (other conditions being equal) was delayed by 10 per cent. of proof spirit from the normal of twelve minutes to eighteen minutes. Even with twice this proportion of alcohol, digestion went on without any embarrassment, but the time of its completion was prolonged from the normal of twelve minutes to forty-five minutes. When we consider how rapidly alcohol is absorbed from the stomach, it is obviously almost impossible that the chyme in the duodenum should ever contain anything like these proportions of alcohol, so that we may consider that alcohol as used dietetically never interferes with tryptic digestion.

Nor did I find that tea or coffee, even in the proportion of 50 or 60 per cent. of the digesting mixture, had any effect worthy of note. A slight retardation was observed, but not the slightest sign of embarrassment. The results obtained with milk were controlled by experiments made with bread, with meat, and with fish-fibre—all of which yielded conformable results. It may, therefore, be concluded that with regard to pancreatic digestion the effects of food-accessories are practically *nil*. In no case did I find evidence of the possibility of that embarrassment and arrest which occurred in so many instances in the case of salivary and peptic digestion.

V.

ON SOME PRACTICAL POINTS IN DIETETICS.

(An Address delivered at the Opening of the Session of the Manchester Medical Society, October 1890.)

SUMMARY :—Two groups of cases require advice on diet, the seriously sick and the substantially healthy—Contradictory advice given to the latter—The proper basis of dietetics is a study of the food-habits of mankind—Man strictly subject to biological laws—Double aim of diet, one to subserve the needs of general nutrition, the other to subserve the needs of the brain and nervous system—What is a luxury ?—Diversity of our diet—Useless and punitive restrictions on the choice of food—Office of the palate in regulating the choice of food—Beneficial effect of change of diet—Better to lessen than to forbid—The neurotic or hysterical stomach—Mid-life revision of the diet—How to restrict the intake of food—Conclusion.

OUR advice is sought in the matter of diet in two different sets of cases. In one set the patient is seriously ill, and disabled more or less completely from pursuing his ordinary avocations ; or he is suffering from some disease which requires a special dietetic treatment, such as diabetes or gastric ulcer. In the other set the patient is only troubled with some slighter ailment or indisposition which does not incapacitate him from taking his part in the world's work, nor necessitate any deviation from his usual habits. In the former class of cases the diet often requires to be entirely transformed, the customary routine has to be abandoned, and the order, quality, and quantity of food have to be rearranged to suit the exigencies of the morbid state, with an almost complete abandonment of any thought as to what might be most suitable in health, and might best promote the success of the individual as an agonist in the struggles and competitions of life. When a man is struck down with fever, or is smitten with some organic disease, we need not consider what diet is best fitted to bring out his physical and mental powers; the business in hand is to advise what is best to keep body and soul together until the fever storm be passed, or what is best to minimise the incidence of the organic trouble, and to lengthen out existence to the utmost possible span.

But the case is far otherwise with the second group, which forms the larger proportion of those who seek our advice, and who question us anxiously as to what they shall eat, drink, and avoid. These have no organic disease, and go about their business or pleasure as usual. They complain perhaps of some dyspeptic trouble, some bodily discomfort, or mental worry or weariness; or of a want of a sense of tranquil and vigorous life; or they are getting on in years, and feel the premonitions of old age; or they belong to that class of neurotics who imagine themselves ill—persons who ponder over their sensations, and give excessive thought as to what they shall eat and what they shall drink. Most of these require of us what aid we can give them by a judicious management of their diet, not only to keep well and live long, but also to maintain that health with maximum vigour, both of body and brain.

Now, with regard to the first group, the advice tendered by us on points of diet displays a fair degree of unanimity. We do not differ much as to the dietetic management of a case of fever, or of diabetes, or of gastric ulcer, or, indeed, of any of the more serious forms of sickness. But, in regard to the second group, in the case of persons who are substantially healthy—and it is of these alone that I propose to speak—the advice tendered by different practitioners is apt to show a lamentable want of consonance, or even a total contradiction. Many patients of this group are persistent seekers after medical advice, and they go about from one adviser to another. The tales some of these have to tell of their dietetic adventures are not pleasant hearing to a medical ear, and are calculated to leave the impression on the public that our notions on dietetics are little better than a farrago of whims and fancies.

All this confusion is, I believe, to be traced mainly to a want of appreciation of the right method of investigating questions relating to diet. I have on previous occasions spoken on this point; but it cannot be too often nor too urgently insisted on that the only true basis of a scientific knowledge of dietetics is to be found in a painstaking and unprejudiced objective study of the food customs and habits of mankind. These customs and habits are as much sober unsophisticated facts of natural history as are the food habits of wild animals. They have grown up by the free play of natural instincts, under the regulating force of universally acting biological laws—under the pressure of the sleepless vigilance of the law of the survival of the fittest and the sure incidence of the laws of heredity. Neither physician nor physiologist has had anything whatever to do with their formation; and, among European communities, and especially among English-speaking communities, the bungling hand of authority has not materially interfered with their normal development.

Some persons appear to think that civilised man is, to a large extent, a denaturalised creature, and they speak of civilisation as if it were the antithesis of Nature. No conception could be more fallacious; for, after all, strictly speaking, civilisation is but a branch of natural history. We can no more withdraw ourselves from the incidence of biological laws than we can from the incidence of physical laws. Biological, like physical, laws are absolutely inexorable, and all the apparatus of our civilisation and all the influences which flow from the initiative of our reason and the action of our intelligence can only modify the conditions under which they operate. I contend, therefore, that we have in our generalised food habits and customs a natural dietetic standard or model —as truly natural as the food habits of the squirrel, the blackbird, or the trout; and, further, that we are warranted in concluding beyond all reasonable doubt that there lies in each main feature of this standard some important beneficial purpose. Considerations of this order, if fully realised by us, would, I think, give greater steadiness and coherence to our notions on dietetics, and bring more uniformity into our rules of practice.

If these views are sound, the office of the medical adviser in matters of diet may be broadly defined to be to adjust the national standard of diet to the special peculiarities and the changing needs of the individual; and in carrying out this adjustment it is his duty to adhere, as far as is practicable, to the main features of that standard.

An attentive examination of the dietetic customs of civilised races reveals very clearly that there are two distinct indications aimed at: one is to subserve the needs of general nutrition, and the other is to subserve the needs of the higher functions of the brain and nervous system. It may be said that bread and other cereal articles, leguminous seeds, the various products of the dairy, fruits and vegetables, the harvest of the sea, and meat, are designed to minister to the former purpose; and that tea and coffee, and the various forms of alcoholic beverages, are designed to minister to the latter purpose. With this second group should also be classed tobacco; for although tobacco cannot be regarded as food, its use must be ranked with our dietetic customs. Strictly speaking, meat, or at least some kinds of meat, should probably find a place in both categories, for it possesses certain stimulating properties which distinguish it from vegetable and dairy products. Tea and coffee and alcoholic beverages are sometimes branded as luxuries. What is a luxury? You cannot rightly class as luxuries —meaning thereby something that has no solid utility to the species—articles that are in general use among a successful and ascendant community. The very fact that these articles have attained this position is, to a naturalist, evidence sufficient that in some way or other the community as a whole, and in the long run, benefits by their use. The struggle for existence—or rather, for a higher and better existence—among civilised men is almost exclusively a brain struggle; and these brain-foods,[1] as they have been not inappropriately termed, must be regarded as a very important part of the equipment for that struggle.

One of the most characteristic features of our national dietary is its *variety or diversity*. Not only are our several daily meals framed on a different plan, but the meals of one day differ more or less from the corresponding meals of another day. We may be quite sure that this diversity serves some useful end. In drawing up schemes of diet we are not, therefore, justified in neglecting this feature and in reducing the diet list to a dead level of monotonous uniformity. A want of attention to this point leads us unwittingly to needlessly torment and worry our patients by placing unnecessary restrictions on their choice of food. Some of those commonly imposed are difficult to understand. There is to be observed a sort of fashion running through these restrictions, yet I know not on whose authority they repose. I do not think it is any medical authority. My impression is that most of them derive their origin from some crude notions floating through the lay press, and unconsciously lodged in the medical mind. Why, for example, should tea and coffee be so frequently forbidden without any evidence that they disagree with the patient? Or why should the bland, innocuous, and easily digested potato be so ruthlessly proscribed? Sometimes prohibition takes a wider sweep, and fruit and vegetables are included in one general condemnation. Nor are the rules laid down always self-consistent. Sugar is forbidden while farinaceous matters are permitted, although, as is well known, these latter are all transmuted into sugar in the course of the digestive operations. Mutton is sanctioned, while beef (of which certain parts are quite as digestible) is denied; or both beef and mutton are condemned, while poultry and game are recommended. These kinds of restrictions are, for the most part, quite unmeaning; they stand on no ground of science nor of experience, and are gratuitously punitive to our patients. Some patients, I admit, seem to derive a sort of grim satisfaction from their dietetic fetters, and come to regard them almost as a mark of distinction; but to most persons these restrictions are very irksome, or even unendurable; and, indeed, many patients break through them, and may sometimes be heard complacently relating how they profited by their rebellion. I remember, some years ago, an amusing instance in point, where I was myself one of the incriminated parties. A fine old gentleman in this neighbourhood, on account of some vesical trouble, had his port wine, to which he was very partial, entirely cut off. His convalescence proved tedious and halting, and still the port wine was withheld. On some special occasion—I forget what—his powers of resistance gave way, and out came the port wine; and he used to recount with glee that he never looked behind him after. I hope I have learnt some useful lessons since then.

---

[1] Of course, this term is used not in a literal, but in a figurative, sense.

Now there is, I think, one very good rule in regard to the regulation of the diet in cases where there are no special indications to fulfil, and that is to put two questions to the patient when he inquires whether he may take this or that article of food—namely, Do you like it? and, Does it agree with you? If the answer be in the affirmative, there is no intelligible reason why the use of that article should not be sanctioned. Such a rule is so plain and simple, and so obviously consonant with good sense, that it might scarcely appear worth while, or even dignified, to make formal mention of it, and I would not have done so had I not been satisfied, from actual experience, that it is constantly violated.

The *indications of the palate* are of great importance in the regulation of the diet, and should always be inquired into and carefully considered. The palate is placed like a dietetic conscience at the entrance gate of food, and its appointed function is to pass summary judgment on the wholesomeness or unwholesomeness of the articles presented to it. It acts under the influence of a natural instinct, which is rarely at fault. This instinct represents an immense accumulation of experience, partly acquired and partly inherited. It is, of course, not infallible—no instinct is, but so close and true are the sympathies of the palate with the stomach and the rest of the organism, that its dictates are entitled to the utmost deference as those of the rightful authority in the choice of food. I am of course aware that the palate—or, rather, the civilised palate—is not always credited with these solid good qualities. Some persons there are—not medical authorities—who distrust its office, and regard its indications with suspicion, as if they were the suggestions of some frivolous and wanton agency, tempting men to a vain gratification of the senses, rather than as those of an honest and skilful guide in the choice of food. This puritanical view of the palate is wholly unscientific; it moreover implies, to speak figuratively, a gross slander on a responsible and rarely endowed organ which has performed in the past, and still performs, most difficult and most complicated functions with conspicuous success; for who shall venture to say, that in the evolution of the human animal from the short-lived, immoral, and stupid savage with his diet of wild fruit, roots, raw flesh, and unfiltered water to the status of civilised man, the promptings of the palate have not played an important and even indispensable part? We are apt to forget that there is no such a thing as an absolutely good or an absolutely bad flavour to the animal palate. Sweet things are indifferent to the palate of the carnivora; and, conversely, the taste of flesh has no attraction for the herbivora. Each animal has its own gustatory standard, which is accurately adjusted to the wants of its particular economy.

It must, however, be admitted that this eulogium applies rather to the typical or general palate than to the particular palate. Man is the most individual of all creatures, and his palate fully shares in this characteristic. And while it is true that the normal or average palate indicates automatically and correctly, not only the due quality, but also the due quantity, of the eating and drinking, there are other palates that require more or less of the control of reason to steady their indications. Then there are eccentric or misfitting palates that appear—if one might so express it—as if they belonged to somebody else—palates which are not inherently defective, but which stand, in one or two particulars, in sharp discord with the organism to which they are attached. And, lastly, there are palates which are altogether perverse and depraved; that habitually betray their hosts, and lead them into endless digestive and other troubles. It is the business of the medical adviser to diagnosticate these eccentric or vicious palates, and to assist their owners by judicious counsel how best to neutralise their evil promptings, and to train them if possible—for the palate is, to a certain extent, an educable organ—to a more wholesome and more harmonious performance of their functions.

The next point to which I would call your attention is the advantage to be gained from *change of diet.* A readjustment of the quality of the meals has often the happiest effect. Change of diet is as refreshing as change of air. The gratifying results are sometimes credited to the skill of the medical adviser in making an improved selection of food when they are really due to the change itself. A course of two or three weeks of vegetarian *regimen* occasionally proves most grateful, especially in the case of habitually heavy feeders—and, similarly, a course of total abstinence from alcoholic beverages is often highly salutary, and, most of all, for those whose daily potations are on a liberal scale. The good effect of mere change of diet is, I think, deserving of more attention than it has hitherto received. There need not be such a departure from the general plan as is involved in vegetarianism or total abstinence. Slighter alterations are often of signal benefit—changes from tea to coffee or cocoa—from one kind of alcoholic beverage to another—from one sort of bread to another. Again, a revision of the order and times of the meals is sometimes beneficial. I have seen more than once an alteration from a mid-day dinner to a late dinner or substantial supper effective in removing a troublesome insomnia. In carrying out plans of change of diet it should ever be borne in mind that the effect is temporary, and that its benefits are exhausted in two or three weeks, or a month or two at the most, and that then a return to the old diet or a new change may be desirable.

Another point of practical interest is this: when certain articles disagree, it is *better to lessen the quantity than to forbid*. If fruit and vegetables prove difficult of digestion, it is certainly unwise to prohibit them altogether. It will generally be found that if the quantities are reduced to a certain level they can be tolerated and enjoyed. The antiscorbutic properties of fruit and vegetables cannot be safely foregone; and a very small proportion suffices to fulfil this indication. I may again refer to the use of potatoes. People do, no doubt, sometimes unduly stuff their stomachs with potatoes, which the organ finds difficult to deal with. But many persons cannot enjoy, or scarcely eat, their dinners without potatoes, and to abstain from them is a great privation. Nor is this necessary; a reduced allowance solves the dilemma perfectly. Then, again, some persons are abnormally sensitive to tea or coffee or alcoholic beverages, and suffer discomfort from the quantities usually taken

But abnormal sensitiveness is not a proof that the incriminated article is unserviceable; and a diminution of the quantity may prove a better remedy than total prohibition. Your late distinguished townsman, Dr. Angus Smith, was hypersensitive to tea, but he did not abstain from it. He was in the habit of taking a tablespoonful or two of ordinary tea, and filling up the cup with water; and he used to declare that he derived as much cheer and refreshment from this weak dilution as other people did from their stronger concoctions. While on this subject I may mention a useful suggestion which we owe, I believe, to Sir Andrew Clark—namely, that sensitive persons should take their tea infused for a very short time, only for one or two minutes. There are, as is well known, idiosyncrasies in which some particular article cannot be tolerated even in the smallest proportions; prohibition is then a necessity. Much more common are the instances in which there is defective self-control as to quantity. This is especially the case with alcoholic beverages. Self-control is indispensable for the salutary use of these articles; and in the absence of this quality there is no safety except in total abstinence.

I animadverted awhile ago on the practice of imposing punitive restrictions on the choice of food; but there are cases in which a certain amount of coercion is salutary, and even necessary. In *neurotic and hysterical persons* the stomach sometimes shares in the general nerve instability, or it may even be the chief offender. This kind of stomach, if indulged in its whims, is apt, like other pampered beings, to give itself airs—it won't have this and it won't have that—and it may even grow proud of its eccentricities. I have known such stomachs reduce their hosts, by successive acts of self-inflicted restrictions, to a diet of dry toast and watergruel—with what results of depressed vitality you can easily imagine. In this group of cases the medical adviser may with advantage insist on a gradual return to ordinary diet; and he will often find that the stomach, after a certain recalcitrancy, will submit, and consent to digest ordinary food, perhaps to the astonishment of the patient, and certainly to the common advantage of the organism. Patients of this class should be given to understand that there are some things worse than an aching stomach—namely, impoverished blood, failing strength, and enfeeble brain and nerve. Moreover, the lower the vitality is reduced by insufficient feeding the more prone is the stomach to neuralgic pains. An enforced administration of more and better food is often the surest as well as the shortest road to deliverance from gastric hyperæsthesia.

The last point I shall advert to is the necessity for a *revision of the diet to meet those changes in the type of nutrition which naturally take place as the individual travels on from youth to age.* Senescence invades the several organs and tissues in a varying order of time; and this want of synchronism is sometimes a source of trouble. When the hair falls off or turns grey before its time, our vanity but not our health is touched. When the teeth decay prematurely, we find succour in the invaluable art of the dentist. But if the prime organs and functions of the body age with unequal steps, the matter is more serious and less easily remedied. As years roll over us the balance of nutrition alters; the exchange of material shrinks, and the organs concerned therein become correspondingly less active and less capable. In the normal course the palate and appetite adjust themselves automatically to these altered conditions, and there is a lessened intake of food. But sometimes this adjustment lags behind. The power of taking food continues unaltered, while the assimilative powers are on the wane: you have the palate and appetite of thirty with the liver and kidneys of sixty. Some form of nutritive disorder necessarily follows. In most of these cases, but not in all, there is a tendency to stoutness. There are indications of digestive difficulties and of engorgement of the abdominal organs, and signs of that vague condition which is termed latent or undeveloped gout. The early recognition of this condition is very important, for thereupon depends the prevention or postponement of degenerative processes which hereafter prove formidable. In this conjuncture the observant medical adviser may render invaluable service in detecting the maladjustment, and in taking timely steps for its correction. The most obvious indication is to lessen the quantity of food, and this is a task of varying difficulty. In many cases of this class—perhaps the majority—the maintenance of an undiminished ingestion of food rests on the force of habit. The accustomed quantity of food and drink is taken, though with a somewhat flagging appetite and lessening gusto. The still small voice of the dietetic conscience is unheeded; or even there may be a little forcing in of the supplies, from a mistaken notion that a falling off might prove disadvantageous, or of evil augury. In these cases an authoritative hint from the medical adviser is sufficient, and is readily accepted and acted on. Full feeders are rarely aware that they eat too much. People constantly délude themselves on this point. I do not know how it is; men often are aware and acknowledge that they drink too much, but they hardly ever allow that they eat too much. They will tell you that they eat much less than most other men they meet with, and insist that they consider themselves to be moderate, or even small, eaters; and it is difficult or impossible to persuade them to the contrary. Possibly they are apt unconsciously to compare themselves with younger men. The medical adviser must in this matter rely mainly on his own judgment and on collateral evidence. In some cases, however, there is much more difficulty in controlling the intake of food. The appetite is really strong, and the powers of digestion—at least of gastric digestion—are abnormally active. Unsatisfied hunger is a painful and an urgent guest, and, with plenty at hand, is hard to resist. The less concentrated forms of food are here a useful resource—green vegetables, salads, and thin soups, which help to fill the aching void without adding materially to the albuminoid and fatty ingredients of the meal. Tea and coffee are also serviceable in allaying an unseasonable craving for food. A stiff cup of tea or coffee shortly before dinner certainly takes the edge off a troublesome appetite. It is, however, well to proceed cautiously and tentatively in this direction, for the promptings of Nature, however apparently to us misdirected, are not to be lightly set aside. The effects of a contracted diet should be carefully and patiently watched, with an open mind for every sign or suggestion, whether of warning to retreat or of encouragement to advance. I need hardly add that in regard to this middle-life revision of the dietary, as it may be termed, particular attention should be given to the quantity of alcoholic beverages. As a very general rule the tolerance for these articles diminishes with advancing years, and it is necessary nearly always with persons who have used them freely to reduce their quantity when middle age is reached.

In regulating the diet of substantially healthy persons, it is imperative to beware of hard-and-fast lines. Cases of this group are very diverse; scarcely any two are exactly alike, and their management is complicated often by moral and social considerations which are difficult to justly estimate. We can only hope to avoid serious errors by a patient investigation of each particular case, and by bringing to bear upon it a full knowledge, combined with a large infusion of common-sense.

SECTION III

PREPARATION OF FOOD FOR INVALIDS

I.

PREPARATION OF ORDINARY FOODS FOR INVALIDS.

(*Abstracted chiefly from an address on 'Feeding the Sick,' delivered before the British Medical Association at Cardiff in* 1885.)

SUMMARY:—Effects of cooking—Clinical relations of gastric and intestinal digestion—Feeding the sick with liquid food—Milk—Beef-tea and other meat decoctions—Cold-made infusions of meat—Beaten-up eggs—Fortified gruels—Different kinds of farinaceous flours—Commercial 'foods' for invalids—Apparatus and ingredients requisite for the preparation of foods in the sick-room and nursery—'Wholemeal' flour.

EFFECTS OF COOKING ON FOOD.

THE process of cooking fulfils far more important ends than that of improving the savour of food—far more important even than the mechanical disintegration which generally attends the process. It produces certain chemical changes in several of the most important alimentary principles which render them incomparably more susceptible to the action of the digestive ferments than in the uncooked state. The discovery of the use of fire-heat in the preparation of his food must indeed have constituted one of the earliest and most important steps in the process by which man has emerged from the ranks of the dumb creation. The stores of proteid and farinaceous nutriment contained in the seeds of cereals and leguminous plants, and in the bulbs, tubers, roots, and succulent stems of certain vegetables are, in the raw state, nearly altogether beyond his powers of digestion. By the discovery of the art of cooking these immeasurable stores were at one stroke laid open to him. It is moreover chiefly by the same art that he has been enabled to take his food at intervals, in separate meals, and has thereby been for ever relieved from the necessity which is imposed on all animals in the wild state of having to spend almost the entire of their waking hours either in seeking after their food, like the carnivora, or in consuming their food like the vegetable feeders. This immunity secured to him the untold advantage of possessing the leisure requisite for the cultivation of his higher faculties.

The practice of cooking is not equally necessary in regard to all articles of food. There are important differences in this respect, and it is interesting to note how correctly the experience of mankind has guided them in this matter. The articles of food which we still use in the uncooked state are comparatively few; and it is not difficult in each case to indicate the reason of the exemption. Fruits, which we consume largely in the raw state, owe their dietetic value chiefly to the sugar which they contain; but sugar is not altered by cooking. Salads may be regarded more as a relish for other food, and as having a quasi-medicinal purpose, rather than as a substantial source of nutriment. Milk is consumed by us both cooked and uncooked, indifferently, and experiment justifies this indifference; for I found on trial that the digestion of milk by pancreatic extract was not appreciably hastened by previously boiling the milk.

Our practice in regard to the oyster is quite exceptional, and furnishes a striking example of the general correctness of the popular judgment on dietetic questions.

The oyster is almost the only animal substance which we eat habitually, and by preference, in the raw or uncooked state; and it is interesting to know that there is a sound physiological reason at the bottom of this preference. The fawn-coloured mass which constitutes the dainty of the oyster is its liver, and this is little else than a heap of glycogen or animal starch. Associated with the glycogen, but withheld from actual contact with it during life, is its appropriate digestive ferment—the hepatic diastase. The mere crushing of the dainty between the teeth brings these two bodies together, and the glycogen is at once digested without other help by its own diastase. The oyster in the uncooked state, or merely warmed, is, in fact, self-digestive. But the advantage of this provision is wholly lost by cooking, for the heat employed immediately destroys the associated ferment, and a cooked oyster has to be digested, like any other food, by the eater's own digestive powers.

With regard, however, to the staple articles of our food, the practice of cooking them beforehand is universal. In the case of farinaceous articles cooking is actually indispensable. When men under the stress of circumstances have been compelled to subsist on the uncooked grain of the cereals, they have soon fallen into a state of inanition and disease. By the process of cooking, the starch of the grain is not only liberated from its protecting envelopes, but it undergoes a chemical change, by which it is transformed into the gelatinous condition, and this immensely facilitates the attack of the diastasic ferments. A change of equal importance seems to be induced in the proteid matter of the grain. I found that the gluten of wheat was greatly more digestible, by both artificial gastric juice and by pancreatic extract, in the cooked than in the uncooked state. In regard to flesh meat the advantage of cooking consists chiefly in its effects on the connective tissue and the tendinous and aponeurotic structures associated with muscular fibre. These are not merely softened and disintegrated by cooking, but are chemically converted into the soluble and easily digested form of gelatin. I made some instructive observations on the effects of cooking on the contents of the egg. The change induced by cooking on egg albumen is very striking. For the purpose of testing this point, I employed a solution of egg albumen made by mixing white-of-egg with nine times its volume of water. This solution when heated in the water-bath does not coagulate nor sensibly change its appearance, but its behaviour with the digestive ferments is completely altered. In the raw state this solution is attacked very slowly by pepsin and acid, and pancreatic extract has almost no effect on it; but after being cooked in the water-bath, the albumen is rapidly and entirely digested by artificial gastric juice, and a moiety of it is rapidly digested by pancreatic extract.

CLINICAL RELATIONS OF GASTRIC AND INTESTINAL DIGESTION.

In forming a plan of dietary for the sick, distinction must be made between gastric and intestinal digestion. In healthy persons, and invalids of the slighter sort, we must have regard mainly to gastric digestion; but in the seriously sick the stomach becomes often inoperative, and digestion becomes almost exclusively intestinal. The sympathy of the stomach with the general condition of the system is much more active and close than that of the intestine; the former organ approximates more nearly to the animal life of the body, the latter more nearly to the vegetative life. The seriously sick, and especially the febrile sick, are often quite unable to take solid food. When the appetite and power of taking food fails, it fails first with regard to meat, which is, so to speak, the speciality of the stomach, and next in regard to bread. Patients are then reduced to the use of liquid food. In this latter condition the stomach loses its normal office, and becomes merely a conduit to pass on the liquid food to the duodenum—a continuation, as it were, of the œsophagus. Not perhaps that there is, except in extreme cases, an absolute abeyance of gastric secretion and gastric action, but they are reduced to so low an ebb that they count for practically nothing in the work of digestion. In this state of things, when patients are unable to take any solid food, it is quite wonderful to observe, in many cases, that persons who in health were unable to digest milk, or only to digest it with pain and difficulty, are able during illness to take milk in any quantity. The reason of this is obvious. In a state of health milk must be dealt with in the stomach, and the casein is curdled into solid masses; these masses have to be broken up and to be more or less dissolved in the gastric juice before they can traverse the pylorus. In the seriously sick, with an almost paralysed stomach, milk is not meddled with in that viscus. There is neither pepsin nor acid to curdle it, and it passes as a flowing liquid into the duodenum. Arrived there, it encounters the secretion of the still active pancreas, and milk is especially amenable to the action of the pancreatic juice.

In feeding the sick our first consideration, therefore, should be whether we are aiming at feeding the stomach or feeding the duodenum. In the former case, when the patient can take solid food—and this is the diagnostic indication that the stomach still possesses digestive activity—our aim must be to administer meat, bread, eggs, &c., in a state most favourable for peptic digestion. The meat should be well cooked—by preference boiled. It should be finely comminuted either by perfect mastication in the mouth, or (if this be impossible) by pounding in a mortar or beating to a paste with a spoon, as in the preparation of potted meat. Beef-tea and soups should be used sparingly, as should likewise be tea, coffee, and alcoholic beverages. And of these last, the best adapted for weak stomachs are regulated quantities of ardent spirits or of the stronger wines or champagne.

FEEDING THE SICK WITH LIQUID FOOD.

In a considerable number of conditions, our patients are unable to take solid food, and are reduced to the necessity of using food which can be administered in the liquid form. This is usually the case in the febrile state and in serious organic disease, especially of the abdominal organs, and in the terminal stages of almost all diseases. There are other conditions in which, although the patient may have the ability to take solid food, it is not desirable that such food should be administered to him. In narrowing of the pylorus or other part of the digestive tract, in ulceration of the intestinal mucous membrane, it is obviously undesirable to administer articles of food which are capable of forming lumps or masses which may block up the narrowed parts of the intestinal tube, or irritate the ulcerated surfaces. There is thus a large field for the employment of liquid food; and one of the most embarrassing tasks in clinical dietetics is to devise food of this form in sufficient change and variety, and having at the same time an adequate nutritive value. Our resources in this state of things consist of milk, beef-tea, and other meat-decoctions, cold-made meat-infusions, beaten-up eggs, and the various gruels. I propose to make some remarks on each of these articles.

Milk.—By far the most serviceable liquid food we possess is milk. Milk contains, in almost equal proportions, proteid, saccharine, and fatty matter, and is capable alone, as we know, of sustaining life. All plans of feeding the sick on liquid food centre round milk. It can be given alone, or mixed with tea, coffee, or cocoa, or with lime water, soda water, ardent spirits, or with farinaceous gruels of various sorts, or as buttermilk, koumiss, or whey. Were it not for the necessity of change and variety, we should, in a large number of cases, want nothing but milk. It should, however, be remembered that milk is by no means a perfect kind of liquid food. In the course of its digestion in the stomach, milk is coagulated into solid masses, and these masses have to be redissolved before they can be absorbed. Not unfrequently, if milk be given too freely, or when there is excess of acid in the stomach, these curdy masses fail of being dissolved; and they are discharged by vomiting, or they pass down the intestine more or less unchanged, and are ultimately voided with the stools. In this way milk may become an objectionable form of liquid food; these curds may block up a narrowed part of the intestine, or they may undergo putrefactive changes, and thereby irritate the tender or ulcerated mucous membrane. To obviate this drawback we are in the habit of combining milk with an antacid. By this means the formation of curds in the stomach is restrained or wholly prevented. The most common practice is to mix the milk with one-third or one-fourth of its bulk of lime water, and often with the happiest results. But in many instances the symptoms are not thus allayed, and the milk is still discharged in hard and sour curds. Failure in these cases is often solely due to the feeble antacid capacity of lime water. The saturating potency of lime water is in reality very low. Quicklime dissolves in water only to the extent of about half a grain to the fluid ounce. This is only equivalent in saturating power to one grain of chalk or to a grain and a half of bicarbonate of soda. To reach a full antacid effect lime water requires to be given in very large quantities—quantities which are altogether impracticable. Six ounces of lime water are only equal to a single ordinary antacid dose of chalk or bicarbonate of soda. I have repeatedly observed in cases of feeding with milk and lime water, that failure was simply due to the feebleness of the antacid charge, and that when a solution containing five or ten grains per ounce of bicarbonate of soda was substituted for lime water as an admixture with milk a favourable result was at once obtained, and the discharge of hard curds arrested.

Beef-tea and other Meat-decoctions.—Next to milk, in frequency of use and in high esteem, come beef-tea and other meat-decoctions. Long experience has satisfied us in this country of the usefulness of these preparations in feeding the sick. Beef-tea and its congeners (mutton-tea, veal and chicken broth), however, take rank as restoratives and stimulants, rather than as nutrients. They contain no albuminous matter in solution, and the small quantity of gelatin contained in them cannot be of much account. There is a wide-spread misapprehension among the public in regard to the nutritive value of beef-tea. The notion prevails that the nourishing qualities of the meat pass into the decoction, and that the dry hard remnant of meat-fibre which remains undissolved is exhausted of its nutritive properties; and this latter is often given to the cat or dog, or even, as I have known, thrown away as useless rubbish into the midden. A deplorable amount of waste arises from the prevalence of this erroneous notion in the households of many who can ill afford it. The proteid matter of meat is, as you know, quite insoluble in boiling water, or in water heated above 160° Fahr. The ingredients that pass into solution are the sapid extractives and salines of the meat, and nothing more, except some trifling amount of gelatin.[1] The meat-remnant, on the other hand, contains the real nutriment of the meat; and, if this be beaten to a paste with a spoon, or pounded in a mortar, and duly flavoured with salt and other condiments, it constitutes not only a highly nourishing and agreeable, but also an exceedingly digestible, form of food.

Cold-made Infusions of Meat.—The defect in nutritious value of beef-tea led Liebig to suggest the use of cold-made infusions of meat. He recommended that minced beef should be infused in cold water acidulated with a few drops of hydrochloric acid. An infusion so prepared differs essentially from beef-tea in the fact that it contains, in solution, a large amount of albuminoid matter. The addition of the acid is, according to my observations, a needless complication of the process. Infusions quite as rich in albumen were obtained when simple water was used as when the water was acidulated with hydrochloric acid. Infusions made from minced meat with half its weight of water, and allowed to stand for two hours, and then pressed through cloth, were found, on analysis, to contain over four per cent. of dry albumen. This amount of proteid is equivalent to that contained in cow's milk. The nutritive value of such infusions is, therefore, very high. When heated to the boiling point, they coagulate into a solid jelly. Made from beef or mutton, the product has an unpleasant bloody appearance; but, when made from veal, the coloration is much paler. The best preparation, however, is made from the meat off the breast of a chicken. This meat is nearly white, and it yields an infusion which is almost colourless, and which sets, on heating, into a solid white jelly, of very agreeable appearance. Cold-made meat-infusions cannot be heated above 114° Fahr. without becoming turbid from commencing coagulation of albumen. It is, therefore, impossible to cook them without destroying their liquid character. The objection to these infusions is their raw flavour, which to many is highly disagreeable—though some invalids take them without the slightest objection. The best way of covering the raw taste is to add some ordinary beef-tea or a little of Liebig's Extract of Meat. Some prefer a flavour communicated by a slice of lemon, or by the addition of a little claret.[1]

---

[1] These remarks on beef-tea apply equally to Liebig's Extract of Meat, Brand's Essence of Beef, and Valentine's Meat-Juice, all of which give only a slight reaction of albumen with nitric acid.

Beaten-up Eggs.—Another highly nutritive form of liquid food is supplied by raw eggs. The yolk, or white, or both together, are beaten up in various ways and combinations which are well known. Eggs are more easily digested by the stomach in the cooked than in the uncooked state; but, when the stomach is weak and unable to digest solid food, beaten-up eggs pass through it into the duodenum without being meddled with, and are slowly digested in their passage down the intestine. They are incapable of forming lumps or masses, and are, therefore, well adapted for cases of narrowing or ulceration of any part of the digestive tract.

---

[1] Cold-made meat-infusions keep badly. They should be preserved in a cold cellar, or, still better, on ice.

Fortified Gruels.—A very important kind of liquid food is furnished by gruels made with the several kinds of cereal or leguminous seeds. Gruels are not by themselves an agreeable kind of food; they lack flavour; but, mixed with milk or beef-tea, they constitute a valuable addition to our resources in feeding the seriously sick. When prepared from the cereal flours in the usual way, they can only be made of feeble nutritive power, if their liquid character is to be preserved. These flours are very rich in starch, and gruels made from them become thick and pasty if the proportion of flour used in their preparation rise to four or five per cent., and a gruel of this strength does not contain more than one-half per cent. of proteid matter. But, if the meal be mixed beforehand with one-eighth of its weight of ground malt, you can prepare from these flours gruels of much higher nutritive value, and still preserve their liquid character. The diastase of the malt acts upon the thickening starch as the heat rises, and converts it into soluble starch and dextrine. These fortified gruels can be made with as much as 20 per cent. of meal, and still maintain the fluid state.[1] Such gruels contain about two per cent. of proteid matter, and about 14 per cent. of carbo-hydrates, and are admirably adapted, combined with milk or beef-tea, to supply a varied kind of liquid food of highly nutritious character. Mixtures of this class seem especially suited for the nourishment of cases of typhoid fever.

---

[1] This mode of preparing fortified gruels requires a somewhat nice adjustment of temperature for complete success; and without the use of a thermometer, and some practice in the operation, is apt to yield an unsatisfactory result. A better and easier method is to prepare the gruels in the usual way with the unmixed flours, and to thin them afterwards when cool by the addition of a previously prepared malt-infusion. This method is fully described in a subsequent article on 'The use of malt, and especially of malt-infusion, in the predigestion of starchy food.' See p. 219.

Use of the various kinds of Farinaceous Flours.—A matter of interest, in designing food for the sick-room and nursery, is the consideration of the special properties of the several kinds of cereal and leguminous substances used as food. In point of chemical composition, the several kinds of cereal grains are closely allied; still, there are differences between them, and these differences may be of importance. The proteid of wheat is not quite identical with that of oats or barley. On the other hand, leguminous seeds differ importantly in composition from the cereal grains. Taking the lentil as a type of the leguminous group, it is to be observed that lentil-flour contains twice as much proteid matter as wheat or oat flour, and almost twice as much lime. Moreover, the proteid of the leguminous seeds differs materially from that of wheat or oats. These differences are probably of not a little importance in feeding the sick and the young; and, if we had more knowledge and experience in their use, we could perhaps utilise with advantage these several cereal and leguminous products, and combine them in varied ways to meet the indications and necessities of different cases.

You must all have observed how there has grown up in these latter years an enormous trade in prepared 'foods' for infants and invalids. The very success of this trade is some evidence of the usefulness of these articles. Their composition is generally made more or less of a secret, but whatever secret there be must be hidden within a very narrow compass. The several possible flours out of which these 'foods' are mingled can be easily counted—wheat, barley, oat, maize, pea, lentil, and one or two others. These are the ingredients—with malt-flour in some cases—out of which they are all compounded. Now, I cannot help thinking that it would be an advantage both to ourselves and to our patients, if we knew more precisely what we were about in this matter, and if we were in a position to prescribe for infants and invalids the several kinds of farinaceous aliments in proportions known to us, instead of blindly using some mixture of which we know not the exact composition. It is impossible for us to make progress in dietetics on such a path. I can quite believe that these flours have their special excellences, and that they are severally adapted for different cases and conditions. In the first place, they have distinctive flavours, and thereby may be made to contribute to the important end of providing change and variety for the invalid. Moreover, the faculty of 'agreeing' of the different flours, in reference to the individual idiosyncrasy, is a point of not a little significance. Lastly, the difference of chemical composition between the cereal and leguminous flours must have an important bearing on the dietetic uses of these two groups of aliments. It is, I repeat, a serious disadvantage that the control of the preparation of food for the sick-room and nursery should pass from the hands of the medical attendant to those of the purveyor. In the matter of drug-giving, all enlightened practitioners are chary of prescribing secret remedies. Such a practice, it is felt, must be fatal to the intelligent use of drugs. So it is with providing food for the sick. What we want is to have at our disposal a supply of the several articles of food in their simple state, and suitable appliances in connection with the sick-room or nursery for cooking and combining them in various ways according to the exigencies of our patients.

APPARATUS AND INGREDIENTS REQUIRED FOR THE PREPARATION OF FOODS FOR INVALIDS.

If I were asked to enumerate the ingredients and apparatus which are necessary for the cuisine of the sick-room and nursery, I think I could do so very briefly. In addition to the resources of the domestic kitchen and larder, the *sick-room kitchen* should contain a supply of the following flours: oat, maize, malt and lentil flours in a finely pulverised condition, and freed from bran. It should be provided with a solution of sodium bicarbonate, containing twenty grains to the ounce; this would be of use to add to milk when necessary, and to assist in the preparation of peptonised articles of food. Next to these would come a reliable pancreatic extract, and a preparation of pepsin, or rennet, for the production of whey. The associated apparatus should include an enamelled rod thermometer, wherewith the nurse could, when desirable, heat up cold-made infusions of meat to a proper temperature, and regulate the warmth required in the predigestion of food. A double-cased saucepan would form an indispensable item; this makes an admirable hot-water bath for the preparation of beef-tea and fortified gruels. A pair of scales and glass measures would complete the list. Finally, there should be, for the service of the nurse, a card or sheet containing plain directions for the preparation of the various kinds of liquid food.

Given these simple appliances, I see no difficulty, in these days of skilled nursing, in the medical attendant being able to prescribe almost any kind of liquid food for his patients in any combination, and having it served up for the invalid in the most suitable possible manner. There is no difficulty on the part of the miller in producing meals from malt, oats, or lentils, freed from bran and coarser particles, and in nearly as fine a state of preparation as wheaten flour.[1] In this state, these meals are susceptible of much more rapid and perfect cooking than when roughly ground. I have little sympathy with much that has been said of the advantages of whole meal and decorticated flour. It has been alleged that the too complete separation of the outer parts of the grain deprives the flour of its mineral matter. If we lived on bread alone, there would be some force in this objection; but as that is not so, and that we find in milk, meat, fish, eggs, soups, and fresh vegetables, a superabundant provision of mineral matter, and have, moreover, always at our elbows a supply of salt, there can never be any lack of saline materials in our food. The branny matter of the flour is both indigestible and irritating to the primæ viæ; and although it may not injure, or may even be useful, to the strong and healthy, it is quite an unfit element in food designed for the weak and tender membranes of the invalid and infant.

---

[1] Flours of this class can now be readily obtained through any of the large druggists.

II.

PREPARATION AND USE OF ARTIFICIALLY DIGESTED FOOD.

(*Third Lumleian Lecture.*)

SUMMARY :—Introductory Remarks—Pancreatic digestion of milk—Modified casein or metacasein—Directions for the preparation of peptonised articles of food—Peptonised milk—Peptonised gruel—Peptonised milk-gruel—Peptonised soups, jellies, and blancmanges—Peptonised beef-tea—Nutritive value of peptonised food—Clinical experience of peptonised food—In uræmic vomiting—In gastric catarrh—In the crises of cardiac disease—In pernicious anæmia—In gastric ulcer—In pyloric and intestinal obstruction—Use of pancreatic extract as an addition to food shortly before it is eaten—Pancreatic extract as an addition to nutritive enemata.

THE suggestion to administer to invalids artificially digested food appears at first sight a somewhat startling proposal. So great an interference with the order of nature would seem to go beyond the legitimate province of art. But when we reflect how largely art already interferes in the preparation of our food, the taking of this further step will appear less surprising. The practice of cooking is in reality as complete a departure from the ways of untutored nature as artificial digestion would be. Among the almost countless species of animals, not one of them, except man alone, cooks his food, insomuch that man has, not inaptly, been defined as the cooking animal.

My previous remarks on the effects of cooking (see p. 177, *et seq.*) go to show that the changes impressed on food by cooking form an integral part of the work of digestion—a part which we of the human race get done for us by the agency of artificial heat—but a part which the lower animals are compelled to perform by the labour of their own digestive organs. It must also be borne in mind that the digestive process carried on in the alimentary canal is, strictly speaking, executed on a doubling of the exterior surface, and not in the true interior of the body. If we take these considerations into account, it will appear, I think, not unnatural that we should try to help our invalids by administering their food in an already digested, or partially digested, condition. We should thereby only be adding one more to the numberless artificial contrivances with which our civilised life is surrounded.

Dr. Pavy[1] was, I believe, the first to carry into actual practice the idea of preparing an artificially digested food. At his suggestion, Messrs. Darby and Gosden introduced a preparation which consisted of meat reduced to a fluid state by artificial digestion. The formula for this preparation has not, so far as I know, been made public. It is still in the market,[2] and is sent out and advertised by Savory and Moore under the title of 'Darby's Peptonised Fluid Meat.' A specimen of this preparation is on the table before me. It has the appearance of a light brown very thick treacle. It has a strong salt taste and an agreeable meaty flavour, without any bitterness. It is mostly soluble in water. The solution does not precipitate on boiling, nor with nitric acid, and it gives a strong reaction of peptone with Fehling's solution, and with tannin.

I have also before me a specimen of artificially digested meat prepared by Mr. Benger. It is a greyish-looking extract, with a pleasant meaty flavour, and is quite devoid of bitterness. It dissolves mostly in water, and the solution gives the usual reactions of peptone in great intensity. Mr. Benger informs me that it is made by operating at a temperature of about 140° Fahr., on finely triturated raw beef with pancreatic extract and a little carbonate of soda. The solution thus obtained is neutralised with hydrochloric acid, and then evaporated at 212° Fahr. to the consistency of a solid extract. Both of these preparations appear to me to be much superior in value to any of the meat extracts hitherto introduced.

---

[1] *A Treatise on Food and Dietetics.* 2nd ed., p. 559.

[2] This was written in 1880.

But however useful preparations of this class may prove to be, in a limited range of circumstances, it is pretty evident that if artificially digested food is to be employed on a large scale, and among all classes, means must be found to bring the preparation of it within the range of culinary operations and the apparatus of the kitchen and sick-room.

The difficulty hitherto encountered in the production of an artificially digested or peptonised[1] food suitable for invalids, is mainly owing to the use of the gastric method in its preparation. If you subject any native article of food—say milk, bread, egg, or meat—to artificial digestion with pepsin and hydrochloric acid, you destroy more or less completely the grateful odour and taste, and the inviting appearance, which made it desirable as food, and convert it into an unsavoury mess, from which the human palate turns away with disgust. The unsavouriness of artificially digested food is, however, not due to any ill taste or smell inherent in the products of digestion—which, when purified, are both odourless and free from any unpleasant flavour—but to a number of bye-products of various kinds, which accumulate as digestion proceeds. One of these bye-products is a substance with a pure bitter flavour, which seems to be a constant accompaniment of gastric digestion. It is also developed in some cases in the later stages of pancreatic digestion. I have not observed this bitter substance, except in the digestion of proteids. It is evidently a normal educt of the process, and its presence probably accounts, in most cases, for the bitter flavour of the eructations of which dyspeptics complain, and which is generally attributed to the regurgitation of bile. It would be interesting to know more about this subject.

---

[1] I may be permitted to use the word 'peptonised' as a convenient abbreviation for the phrase 'artificially digested.'

My own efforts to produce a palatable peptonised food have been chiefly directed to the pancreatic method. The pancreas excels the stomach as a digestive organ, in that it has power to digest the two great alimentary principles, starch and proteids; and an extract of the gland is possessed of similar endowments. This double power is a manifest advantage in dealing with vegetable aliments, which contain both starch and proteids.

Any extract of pancreas may be used for the preparation of artificially digested food, but the most suitable are those prepared with dilute spirit or chloroform water. The extract sent out by Mr. Benger, under the name of 'Liquor Pancreaticus,'[1] is an almost faultless pharmaceutical preparation. It is made by extracting perfectly fresh and finely chopped pancreas with four times its weight of dilute spirit. By some ingenious devices, Mr. Benger has succeeded in overcoming the mechanical difficulties of the manufacture, and has produced an extract which possesses the diastasic and proteolytic properties of the pancreas in a highly concentrated degree.

---

[1] Sent out by Mottershead & Co., chemists, Manchester.

It is a nearly colourless solution, with very little taste or smell beyond that of the spirit used to preserve it. It is of this preparation that I must be understood to speak in what I have now to say on the production of artificially digested food by pancreatic extracts.

My attention was first turned to the artificial digestion of milk, and I soon found that it was possible, by means of pancreatic extract, to digest this important article of food with comparatively little disturbance of its taste and appearance. Milk contains all the elements of a perfect food, adjusted in their due proportion for the nutrition of the body. Two out of its three organic constituents—namely, the sugar and the fat—exist already in the most favourable condition for absorption, and require little, if any, further assistance from the digestive ferments. It is therefore obvious that if we could change the casein of milk into peptone without materially altering the flavour and appearance of the milk, such a result would go far towards solving the problem of supplying an artificially digested food for the use of the sick.

PANCREATIC DIGESTION OF MILK.

When milk is subjected to the action of pancreatic extract, at a temperature of 100° F. (38° C.), in an open glass vessel, a series of changes take place in it which are highly interesting to watch. The first thing that arrests the observer's notice is that the tough wrinkled skin which quickly forms on the surface of warm milk when exposed to the air is either not produced at all, or is only produced in a very imperfect degree. In its stead there forms a slight brittle and perfectly smooth pellicle of quite a different appearance. The next thing noticed is that the milk becomes more or less softly curdled. By-and-bye the curds begin to redissolve, and the milk gradually reassumes its originally diffluent condition. A portion of the curd is, however, very resistant, and remains undissolved for many hours. If the milk be diluted beforehand with one-third or one-fourth of its bulk of water, this curdling phase is altogether omitted, or is only observed as a slight and transient thickening. Next follows a very curious change of aspect. The milk loses its glossy white appearance, and gradually assumes a dull yellowish-grey shade which is characteristic, and the degree of which enables the practised eye to judge with considerable precision how far the peptonising process has advanced. This change of aspect is, however, by no means conspicuous, and would scarcely be remarked in a cursory observation, except by comparison with unaltered milk. While these changes are proceeding, the milk gradually loses its proper flavour, and at length develops a pure bitter taste, which is to many palates not disagreeable. No really unpleasant flavour is produced unless the process be allowed to go on to incipient decomposition.

The progressive transformation of the casein into peptone, of which these outward signs are the indications and accompaniments, may be followed by testing the milk from time to time with acetic acid. At first the addition of the acid causes an abundant precipitation of curdy matter, but this reaction progressively diminishes in intensity until at length it ceases altogether. When this point is reached the transformation may be regarded as complete. All the casein has been changed into peptone—even nitric acid no longer causes a precipitate. The time occupied in the transformation (supposing the temperature and the activity of the preparation to be constant) depends on the quantity of pancreatic extract added, and may be made to vary from a few minutes to several hours. In the ordinary operation of preparing peptonised milk for invalids, two or three teaspoonfuls of the liquor pancreaticus are added to one pint of milk diluted with a third of its bulk of water. With these proportions, and at a temperature of 100° Fahr., the process is usually completed in from two and a half to three hours.

Modified Casein or Metacasein.—The conversion of casein into peptone does not take place by a direct transformation of the one body into the other. You all know that milk does not curdle or coagulate in the least degree on being boiled, but when milk is subjected to the action of pancreatic extract (provided no alkali be added) it speedily loses this negative property, and curdles abundantly on boiling. This coagulation on boiling is most intense soon after the addition of the extract, and it very gradually diminishes in intensity as the action goes on, and ceases altogether about the same time that acetic acid ceases to cause a precipitate. It was, moreover, found that if the milk was boiled at the period of the greatest intensity of this reaction, and thrown on a filter, the whole of the albuminoid matter of the milk was caught on the filter in the form of curds, and the filtrate showed not the slightest reaction of casein. These reactions revealed the interesting fact that in the transformation of casein into peptone by pancreatic extract, the first step in the process is the conversion of casein into an intermediate body, and that it is this intermediate body which is subsequently gradually changed into peptone. This body may provisionally be called *metacasein*, signifying thereby that it is still casein, but in a modified condition. Metacasein is characterised by two reactions, which, taken together, serve to distinguish it from other proteid bodies—it is coagulated by boiling in neutral media, and it is precipitated in the cold by acetic acid. The conversion of casein into metacasein in pancreatic digestion takes place almost suddenly, as is shown by the following experiment:—5 cubic centimeters of pancreatic extract were added to 100 cubic centimeters of milk, diluted with one-fourth of its bulk of water, and maintained at blood-heat. The first slight, almost doubtful, evidence of coagulation on boiling was perceived in three minutes; in five minutes coagulation on boiling was pronounced; and in nine minutes it had reached its maximum. From this point coagulation on boiling, and precipitation on the addition of acetic acid, diminished in intensity *pari passu* very gradually for a period of two hours, when both reactions finally ceased.

Taking these observations and reactions together, it is evident that the conversion of casein into metacasein constitutes a first and distinct step in the transformation of casein by trypsin, and that this step is antecedent to the further and slower changes by which metacasein is transmuted into peptone. It is impossible not to see in this a striking analogy with the sudden transformation of gelatinous starch into soluble starch under the action of diastase, as described on a previous page (p. 20).

When milk is rendered slightly alkaline by the previous addition of a little bicarbonate of soda, no precipitation on boiling occurs during its digestion by pancreatic extract. But the metacasein is nevertheless produced, and its presence may be detected by carefully saturating the alkali, and then boiling. For although metacasein is precipitated on boiling when the solution is neutral, it is not precipitated when the solution is even slightly alkaline. This is the reason why, in preparing peptonised milk for the sick, it is desirable to add to it a small quantity of bicarbonate of soda.

The foregoing account of the behaviour of milk with pancreatic extract will greatly facilitate the comprehension of the practical rules which must be followed in preparing peptonised dishes for invalids.

DIRECTIONS FOR THE PREPARATION OF PEPTONISED ARTICLES OF FOOD.

Peptonised Milk.—A pint of milk is diluted with a quarter of a pint of water, and heated to a temperature of about 140° F. (60° C.). Two teaspoonfuls of liquor pancreaticus, together with twenty grains of bicarbonate of soda, are then mixed therewith. The mixture is then poured into a covered jug, and the jug is placed in a warm situation in order to keep up the heat. At the end of an hour or an hour and half the product is raised to the boiling point. It can then be used like ordinary milk.

The object of diluting the milk is to prevent the curdling which would otherwise occur and greatly delay the peptonising process. The addition of bicarbonate of soda prevents coagulation during the final boiling, and also hastens the process. The purpose of the final boiling is to put a stop to the ferment action when this has reached the desired degree, and thereby to prevent certain ulterior changes which would render the product less palatable. The degree to which the peptonising change has advanced is best judged of by the development of the bitter flavour. The point aimed at is to carry the change so far that the bitter taste is faintly perceived, but is not unpleasantly pronounced. As it is impossible to obtain pancreatic extracts of absolutely constant strength, the directions as to time and quantity must be understood with a certain latitude. The extent of the peptonising action can be regulated either by increasing or diminishing the dose of the liquor pancreaticus, or by increasing or diminishing the time during which it is allowed to operate. By skimming the milk beforehand, and restoring the cream after the final boiling, the product is rendered more palatable and more milk-like in appearance.

Preparation of Peptonised Milk in the Cold.—The action of pancreatic extract on milk goes on at the ordinary temperature of the air exactly in the same way as at blood-heat—except that it is slower, and requires a longer time for completion. The cold method has, however, a convenience and simplicity which recommends it for general use in the sick-room. I have accordingly drawn up the following directions for the preparation of peptonised milk at a temperature of 60° to 65° Fahr., which may be regarded as the ordinary degree of warmth maintained in rooms occupied by invalids. In the winter season it will be necessary to slightly warm the ingredients beforehand in order to bring them to the due temperature, but in the warmer seasons the operations can be carried on without any preliminary heating.

A pint of milk is diluted with half a pint of *lime-water*[1] —or with half a pint of water containing twenty grains of bicarbonate of soda in solution. To this are added three teaspoonfuls of liquor pancreaticus. The mixture is then set aside in a jug or other convenient vessel, in the sick-room, for a period of three or four hours. At the expiration of this time the milk is far advanced in the process of digestion, and has developed a slightly bitter taste. It is now ready for use. It may be used cold, either alone, or with soda-water, which covers the bitterish taste remarkably well—or it may be warmed and sweetened for administration to infants.

---

[1] I owe the suggestion to use lime-water to Dr. Watkins, of Newton-le-Willows.

If milk thus prepared be consumed at the period indicated—that is to say, at the end of three or four hours, it need not undergo any final boiling—it is better, indeed, to use it without boiling, because the half-finished process of digestion will still go on for a time in the stomach. But if milk thus prepared has to be kept much longer, it is advisable to raise it for a moment to the boiling point, so as to bring the action of the ferment to a termination, and thus to prevent those ulterior changes which render the product disagreeable to the palate.

The process can be regulated with the utmost nicety by occasionally tasting the mixture, and watching the development of the bitter flavour—and it can be permanently arrested at any moment by heating the product to the boiling point.

Peptonised Gruel.—Gruel may be prepared from any of the numerous farinaceous articles which are in common use—wheaten flour, oatmeal, arrowroot, sago, pearl barley, pea or lentil flour. The gruel should be very well boiled, and made thick and strong. It is then poured into a covered jug, and allowed to cool to a lukewarm temperature. Liquor pancreaticus is then added in the proportion of two teaspoonfuls to the pint of gruel. At the end of three hours the product is boiled and strained. The action of pancreatic extract on gruel is two-fold—the starch of the meal is converted into sugar, and the albuminoid matters are peptonised. The conversion of the starch causes the gruel, however thick it may have been at starting, to become quite thin and watery. The bitter flavour does not appear to be developed in the pancreatic digestion of vegetable proteids, and peptonised gruels are quite devoid of any unpleasant taste. It is difficult to say to what extent the proteids are peptonised in the process of digestion by pancreatic extract. The product, when filtered, gives an abundant reaction of peptone; but there is a considerable amount left of undissolved material. Most of this, no doubt, consists of insoluble vegetable tissue, but it also contains some unliberated amylaceous and albuminous matter. Peptonised gruel is not generally, by itself, an acceptable food for invalids, but in conjunction with peptonised milk (peptonised milk-gruel), or as a basis for peptonised soups, jellies, and blanc-manges, it is likely to prove valuable.

Peptonised Milk-gruel.—This is the preparation of which I have had the most experience in the treatment of the sick, and with which I have obtained the most satisfactory results. It may be regarded as an artificially digested bread-and-milk, and as forming by itself a complete and highly nutritious food for weak digestions. It is very readily made. First, a good thick gruel is prepared from any of the farinaceous articles above mentioned. The gruel, while still hot, is added to an equal quantity of cold milk. The mixture will have a temperature of about 125° F. (52° C.). To each pint (550 cubic centimeters) of this mixture, two teaspoonfuls of liquor pancreaticus, and twenty grains of bicarbonate of soda are added. It is then set aside in a warm place for two or three hours, and finally raised to the boiling point and strained. The bitterness of the digested milk is almost completely covered in the peptonised milk-gruel; and invalids take this compound, if not with relish, without the least objection.

Since the first publication of these lectures, peptonised milk-gruel has found favour with many practitioners, and has come into considerable use among their patients. I find, however, that some persons fail to peptonise milk-gruel so as to make it acceptable to the palate and stomach of the invalid. This is entirely due to allowing the peptonising process to go on too far. Artificial digestion, like cooking, must be regulated as to its degree; and it is easy to regulate the degree of artificial digestion by the length of time during which the process is allowed to go on. It must be remembered that liquor pancreaticus (and every other form of pancreatic extract) is more or less variable in its activity, just as the fires used in cooking vary in their intensity, and that allowance must be made for this variability. If the liquor pancreaticus is very active the slight bitterness, whereby it is known that the process has been carried far enough, is developed in an hour, or less; but if the preparation is not so active two or three hours may be required to reach the same point. It must further be borne in mind that the warmer the temperature at which the process is carried on the quicker is the action of the ferment. The practical rule for guidance is to allow the process to go on until a faintly perceptible bitterness is developed, and not longer. As soon as this point is reached the milk-gruel should be raised to the boiling point, so as to put a stop to further changes.

Peptonised Soups, Jellies, and Blanc-manges.—I have sought to give variety to peptonised dishes by preparing soups, jellies, and blanc-manges containing peptonised aliments. In this endeavour I have been assisted by a member of my family, who has succeeded beyond my expectations. She has been able to place on my table soups, jellies, and blanc-manges containing a large amount of digested starch and digested proteids, possessing excellent flavour, and which the most delicate palate could not accuse of having been tampered with. *Soups* were prepared in two ways. The first way was to add what cooks call 'stock' to an equal quantity of peptonised gruel, or peptonised milk-gruel. A second and better way was to use peptonised gruel, which is quite thin and watery, instead of simple water, for the purpose of extracting shins of beef and other materials employed for the preparation of soup. *Jellies* were prepared simply by adding the due quantity of gelatin or isinglass to hot peptonised gruel, and flavouring the mixture according to taste. *Blanc-manges* were made by treating peptonised milk in the same way, and then adding cream. In preparing all these dishes it is absolutely necessary to complete the operation of peptonising the gruel or the milk even to the final boiling before adding the stiffening ingredient. For if pancreatic extract be allowed to act on the gelatin, the gelatin itself undergoes a process of digestion, and its power of setting on cooling is utterly abolished.

Peptonised Beef-tea.—Half a pound of finely minced lean beef is mixed with a pint of water and 20 grains of bicarbonate of soda. This is simmered for an hour. When it has cooled down to a lukewarm temperature, a tablespoonful of the liquor pancreaticus is added. The mixture is then set aside for three hours, and occasionally stirred. At the end of this time the liquid portions are decanted and boiled for a few seconds. Beef-tea prepared in this way is rich in peptone. It contains about 4·5 per cent. of organic residue, of which more than three-fourths consist of peptone—so that its nutritive value in regard to nitrogenised materials is about equivalent to that of milk. When seasoned with salt it is scarcely distinguishable in taste from ordinary beef-tea.

The extreme solubility of digested products—whether of starch or of proteids—detracts from their acceptability to healthy persons. To them they appear thin and watery —they miss the sense of substance and solidity which is characteristic of their ordinary food. But to the weak invalid without appetite this sense of substance or thickening is generally objectionable, and he takes with more ease an aliment which he can drink like water. The jellies and blanc-manges, on the other hand, give to invalids of more power that sense of resistance and solidity which is desired by those of stronger appetite.

NUTRITIVE VALUE OF PEPTONISED FOOD.

At the outset of this inquiry we are met with the question : Is it certain that the ultimate products of digestion are of equal nutritive value to the mixed transitional products which are produced in succession, and probably absorbed as the food is gradually transformed in the alimentary canal?—in other words, are maltose and peptones alone as valuable to the economy as a mixture of these substances with the several dextrines and hemipeptones which are presented to the absorbent surfaces in the course of natural digestion?

With regard to the products of starch-digestion, no direct experiments have been made on the nutritive value of maltose, and we can do little more than conjecture that the intermediate dextrines have a usefulness of their own. That they are absorbed seems proved (as might have been expected from their known diffusibility), for they have been detected in the blood, and especially in the blood of the portal vein.

With regard to peptones, we have more information. It was naturally assumed by the earlier observers who identified peptone as the chief ultimate product of digestion that this was the form under which proteids were taken up by the absorbents and introduced into the blood for the nutrition of the tissues. But some twenty years ago doubts were cast on this conclusion. It was alleged by Brücke and Voit that the nutrition of the tissues was maintained not by peptone, which was unfitted for this purpose, but by soluble albumen, which was absorbed in the undigested state from the primæ viæ, and that the office of peptone was a subordinate one, resembling that of gelatin, and consisted in aiding to preserve the tissue-albumen from too rapid destruction. Direct observations on the nutritive value of peptones have, however, shown this paradoxical view to be untenable. As the point is one of importance, I will endeavour to lay before you the proofs which have been already adduced of the food-value of peptones, and I will supplement these by some observations made by myself.

P. Plosz[1] was the first to put this question to the test of direct experiment. He fed a puppy dog weighing 1,302 grams with an artificial compound made of fat and sugar, in imitation of milk, but in which the casein was replaced by artificially digested fibrin. In the course of eighteen days of this diet the dog grew and increased 501 grams in weight.

R. Maly[2] performed a similar experiment on a pigeon. He first fed the pigeon for several days on a regulated quantity of wheat until he had ascertained the quantity requisite to keep the bird in a state of nutritive equilibrium, in which it neither gained nor lost weight. He then made an artificial corn from starch, fat, gum, salts, and water, but in which the gluten was replaced by fibrin-peptone, and fed the pigeon on the same quantity of this artificial corn as he had before given of the natural corn. Under this novel diet the bird, after a short apprenticeship, not only maintained its weight, but actually put on flesh. This experiment seemed to show that peptone was even superior to natural gluten as a nutriment.

---

[1] Pflüger's *Archiv f. d. ges. Physiologie*, 1874, p. 323.

[2] *Ibid*, p. 585.

It was, however, objected to these experiments that they did not rigorously prove that peptone could build up the tissues, inasmuch as the increase of weight might have been due to an excessive accumulation of fat or of water, and that there might have been not an increase, but a decrease of the structural elements which contained nitrogen.

To meet these objections, Plosz and Gyergyai[1] instituted a third set of experiments on a dog weighing 2,753 grams. The dog was brought down by a diet of simple water to a weight of 2,531 grams. He was then fed on a mixture composed of sugar, starch, and fat, and containing, in addition, 5 per cent. of purified peptone. Of this mixture about 400 grams were daily administered to the animal for a period of six days. In these six days the dog took in with his food 14·45 grams of nitrogen, but the total of the nitrogen excreted by the urine and fæces only amounted to 13·46 grams, so that nearly one gram of nitrogen had been retained in the body of the animal, which had increased in weight 259 grams. This experiment went to prove that peptone served to repair the wear and tear of the nitrogenised structural elements, and even contributed something to the increase of weight.

Adamkiewicz,[2] by a still more rigorous method, in a laborious series of experiments on a dog which was fed on a diet wherein the only possible source of nitrogen was peptone prepared from blood-fibrin, arrived at the conclusion that peptone supplied nitrogen to the solid tissues, and that it possessed a nutritive value equal to albumen, or even slightly superior; and that therefore it could not be looked on as a bye-product of digestion, but as the chief resultant of the transformation of proteids in the alimentary canal.

---

[1] Pflüger's *Archiv*, Bd. x. 1875, p. 536.

[2] *Natur und Nahrwerth des Peptons*. Berlin, 1877.

The experiments above cited seem sufficient to settle definitely the question raised by Brücke and Voit, and to establish the nutritive value of peptone as a source of nitrogen to the tissues. It seemed, however, desirable to obtain direct proof of the nutritive value of peptonised milk as compared with the natural article. My observations led me to the conclusion that it was easier to get a supply of peptonised aliment suitable for invalids by the artificial digestion of milk by pancreatic extract than by any other method. But in so important a matter as the feeding of invalids, inference and conjecture seemed hardly a sufficient basis for actual practice.

The questions I proposed to myself were—(1) Is artificially digested, or peptonised, milk alone sufficient to sustain nutrition? and (2) is it as efficient in this respect as natural milk? For the purpose of answering these questions I procured four kittens, of the same brood, eight weeks old. Kittens at this age thrive perfectly on an exclusively milk diet. Two of the kittens were fed on natural milk, and the other two on milk previously digested by pancreatic extract. The digestion of the milk in the latter case was carried out to full completion—that is to say, until the milk became greyish and bitter, and no longer gave any precipitate with acetic acid, nor even with nitric acid. The animals were permitted to have as much of their respective foods as they could consume. The experiment was continued for a period of twenty days. The quantity consumed by each pair was as nearly as possible the same. All four continued in perfect health, and took their nutriment greedily. I was surprised to find that the pair fed on peptonised milk showed no repugnance to the bitter taste of their food, but appeared to relish it quite as well as their companions did their natural milk. The following table exhibits the gain in weight at the end of twenty days by each of the four kittens. The weights are given in grams and in round numbers.

Diet	Initial Weight	Weight at the end of 20 days	Increase of Weight	Increase of Weight per cent.
Natural milk	No. 1—338	514	176	52
	„ 2—558	835	280	50
Fully peptonised milk	„ 3—403	626	223	55
	„ 4—374	562	188	50

The table shows that the percentage increase of weight was very nearly alike in all four animals. No difference could be perceived in the sleekness of their coats nor in the vivacity of their gambols. The experiment proves that peptonising the milk in no degree spoils its nutritive value. It also shows, as might have been expected, that in healthy animals with abundance of digestive power there is no advantage to be gained from the administration of food in a predigested state. The quantity of food which is taken and absorbed appears to be regulated not so much by the quantity which can be digested as by the quantity which can be assimilated. This experiment had an interesting sequel. After Nos. 3 and 4 had been fed on *fully* peptonised milk for a period of twenty days, they were fed for a period of ten days on *partially* peptonised milk. By using a less quantity of the pancreatic extract in proportion to the milk, and by allowing the process of artificial digestion to go on for not more than half the time allowed in the previous experiment, only a partial conversion of the casein was effected. As nearl as I could judge by the precipitate caused with aceti acid, the casein was digested to about the extent of on half. Under these circumstances I certainly expected that Nos. 3 and 4 would gain weight as before, and would continue to thrive as well as Nos. 1 and 2. It might have been anticipated that under these new conditions the proper digestive powers of Nos. 3 and 4 would come into play and complete with ease the unfinished work of the artificial process. But events did not pass exactly as I anticipated. The annexed table shows the actual results. The weights, as before, are given in grams.

Diet	Initial Weight	Weight on 3rd day	Weight on 5th day	Weight on 7th day	Weight on 10th day
Natural milk	No. 1—514	551—gain 37	570—gain 19	593—gain 23	618—gain 25
	„ 2—838	900— „ 62	936— „ 36	993— „ 57	1063— „ 70
Half-peptonised milk	„ 3—626	693— „ 67	687—loss 6	681—loss 6	693— „ 12
	„ 4—562	645— „ 83	638— „ 7	648—gain 10	683— „ 35

No interval was allowed to elapse between the two sets of experiments, so that the initial weights in the second set are the same as the terminal weights in the first set. The abrupt alteration in the diet of Nos. 3 and 4 produced a marked disturbance in their nutrition. But there was no declension in their general well-being, and they continued to take their modified diet with the same avidity as before. In the first three days Nos. 3 and 4 showed an unusual increase of weight—an increase quite out of proportion to that of their companions. Then came a check; in the next four days they not only showed no gain, but showed even a slight loss of weight. In the last three days they began to gain weight again, and were evidently recovering from the temporary check caused by their change of diet. The explanation of this series of events which has presented itself to my mind is the following, but I by no means wish to lay stress on its accuracy. It seemed as if the enforced rest imposed on the digestive organs for a period of twenty days, during the use of fully predigested food, had temporarily diminished their natural vigour—just in the same way as the disuse of a limb diminishes for a time the strength of its muscles. During this first period, immediately following the change of diet, the unemployed digestive powers were suddenly called upon to resume their wonted activity; but, owing to their enfeeblement from disuse, they were unable to respond to the call with due promptness, and undigested materials accumulated in the intestines. This accumulation accounted for the unusual increase in weight during the first period. During the next period the digestive embarrassment made itself felt, and gave a check to the processes of growth and nutrition, and the animals ceased to grow and gain weight. During the last period the temporary enfeeblement of the digestive organs was passing away, in proportion as renewed exercise was restoring them to their original vigour, and growth and increase of weight again commenced.

Whether this explanation be trustworthy or not, the lesson indicated by it is probably a true one—namely, that except in extreme cases, when the digestive power is wholly lost or in complete abeyance, it is more advantageous to use a food which has been subjected to partial artificial digestion than food in which the process has been carried out to completion. If the patient possess any digestive power at all, it is better that that power should be kept in exercise than that it should be permitted to deteriorate still further from total disuse. This is in agreement with the rule we apply in other cases of enfeebled function, according to which we endeavour to combine partial rest with moderate exercise.

CLINICAL EXPERIENCE OF PEPTONISED FOOD.

The extreme difficulty of arriving at reliable conclusions in regard to the effect of therapeutical agents is well known to every sober-minded inquirer. The difficulty is not less, but probably greater, in judging of the effects of dietetic means. I have now had a considerable experience, extending over a period of two years,[1] of the use by invalids of peptonised milk and peptonised milk-gruel, and it would be an easy task for me to recite a string of cases in which improvement and recovery followed the use of these articles of diet. But evidence of this sort would be wholly delusive unless checked by such an analysis of the circumstances of each case as would enable me to isolate the influence of the dietetic means. In the immense majority of cases such an analysis would be obviously impossible, the conditions to be taken into account would be too numerous, and their relative influence too difficult to determine. In a question of this kind one is obliged, in a large degree, to fall back on general impressions, and on deductions based on physiological considerations. Nevertheless there are certain cases—most of them cases of incurable disease—in which the conditions are sufficiently simple to permit direct trustworthy conclusions to be drawn.

I found that peptonised milk-gruel was generally preferred, as being more agreeable to the palate, to simple peptonised milk; and by far the larger number of my observations were made with the former preparation. I was also soon satisfied that, with most rare exceptions, peptonised milk-gruel was perfectly acceptable to the invalid's stomach, and that a diet composed exclusively of this article could be used for many consecutive weeks without the slightest sign of failure of nutrition.

---

[1] Written in 1880.

The cases in which the use of peptonised aliment appeared to produce the most striking benefits were those in which complete anorexia prevailed, and those in which the stomach was intolerant of food, and immediately rejected every form of nutriment. A brief review of the results obtained in cases of this kind will, I think, prove instructive.

Uræmic Vomiting.—In advanced Bright's disease incessant vomiting is sometimes a distressing and intractable symptom. In some cases of this class I have seen the vomiting at once and permanently allayed by the use of peptonised milk-gruel. The downward course of the disease may not have been a moment checked, but the relief to the dying patient was great.

Gastric Catarrh.—That form of gastric catarrh which is the Nemesis of alcoholic excess often yields immediately to the use of peptonised food. In the later periods of cirrhosis there frequently prevails severe intolerance of every kind of food—the stomach rejecting even beef-tea and diluted milk in the smallest quantities. The relief afforded by the use of peptonised milk-gruel in some of these cases is most striking—the vomiting ceases almost from the first, and the intolerable sense of distension diminishes.

Crises of Cardiac Disease.—Persons suffering from dilatation and valvular incompetency usually encounter one or more crises which are susceptible of relief before finally succumbing to their disorder. These crises are marked by a general venous stagnation with severe congestion of the lungs, liver, and kidneys, and rapidly rising dropsy. Associated with these symptoms, there is generally almost complete inability to take food, and sleeplessness. In this condition I have seen marked relief follow the use of peptonised aliment. I have long observed, as I doubt not have many of you, that the condition here described is often alleviated in the most striking manner by the use of exclusively liquid nourishment—such as milk or milk-gruel, given in small portions sub-continuously, or sippingly, as it were, throughout the waking hours—the patient being never permitted to take a distinct meal, nor a particle of solid food. As my practice has been to direct, in cases of this class, the administration of the peptonised aliment in this sipping fashion, the gratifying results noted have been partly due to the mode of administration; but I have been convinced by more than one example, when the same liquid nourishment, in the natural and in the predigested condition, has been used in succession, that there was a distinct superiority in the predigested article.

Pernicious Anæmia.—In the earlier periods of this singular disorder, I am inclined to hope that predigested aliment may prove a valuable resource. In cases where the disease, although fully declared, was still of comparatively recent origin, I have, in the last eighteen months, seen the symptoms checked under the use of peptonised milk-gruel. In one case, owing to the irritability of the stomach, the milk-gruel was at first administered per rectum with pancreatic extract, but was afterwards tolerated by the stomach. In three of these cases the amelioration went on to complete restoration. In cases of longer standing I have failed by the same means to obtain the slightest improvement.

Gastric Ulcer.—The use of an exclusively liquid nourishment given sub-continuously, in the manner before indicated, is a well-known and most efficacious mode of treatment in these cases. But since adopting the plan of giving peptonised milk-gruel, I think I have perceived that the results were distinctly better than before, especially in cases associated with epigastric pain. The almost absolute rest procured by this food for the ailing organ appeared to be an additional advantage. I may be permitted to mention one case. The patient had suffered from copious and repeated hæmatemesis, and from severe epigastric pain. The irritability of the stomach was such that the simplest nourishment, given in the smallest quantities, was immediately rejected. Peptonised milk-gruel was, however, tolerated at once; vomiting only occurred two or three times during the two first days of the treatment, and then ceased, as did likewise the epigastric pain. This patient used no other food for a period of six weeks, and took daily from two to three quarts with steady recovery of flesh and strength.

Pyloric and Intestinal Obstruction.—Peptonised aliment would appear to be especially suitable for use in these cases, but, so far, I have been somewhat disappointed in the results. The vomiting has generally been effectually controlled, but I have not been able to convince myself, in cases of pyloric stricture, that the fatal event was delayed even a single day. When the obstruction has been temporary, and due to a removable cause, the results have been of course more satisfactory.

I should be glad to see a further trial made of peptonised, or partially peptonised, milk in the gastric and intestinal catarrh of infants. In one severe case of this class a favourable result was immediately obtained; in another case there was greater tolerance of food, and more comfort after it, than with the use of simply diluted milk. It would be interesting also to have experience of the use of peptonised aliment in typhoid fever and in old age. The greater variety which can now be given to this form of food by the preparation of peptonised soups, jellies, and blanc-manges will serve to obviate the monotony sometimes complained of under the continuous use of peptonised milk-gruel.

THE USE OF PANCREATIC EXTRACT AS AN ADDITION TO FOOD SHORTLY BEFORE IT IS EATEN.

The administration of pancreatic extract with, or immediately after, a meal can, I think, have only a limited utility. On entering the stomach the pancreatic extract would encounter the acid of the gastric juice, and when this rose above a certain point the activity of the ferments would be destroyed. Still a not inconsiderable interval of time must elapse before this point is reached, and during this interval the pancreatic ferments would accomplish a certain amount of work. I have repeatedly administered pancreatic extract in this way, but I am unable to say positively that I have seen benefit from this mode of administration. There is, however, a modification of this plan, which I have lately put in practice, that promises better results. It is to add the extract to the food fifteen or twenty minutes before it is eaten. Certain dishes commonly used by invalids—farinaceous gruels, milk, bread-and-milk, milk flavoured with tea or coffee or cocoa, and soups strengthened with farinaceous matters, or with milk—are suitable for this mode of treatment. A teaspoonful or two of the liquor pancreaticus should be stirred up with the warm food as soon as it comes to table. And such is the activity of the preparation that even as the invalid is engaged in eating—if he eat leisurely as an invalid should do—a change comes over the contents of the cup or basin—the gruel becomes thinner, the milk alters a shade in colour, or perhaps curdles softly, and the pieces of bread soften. The transformation thus begun goes on for a time in the stomach, and one may believe that before the gastric acid puts a stop to the process the work of digestion is already far advanced.

This mode of administering pancreatic preparations is simple and convenient. No addition of alkali is required, and, of course, no final boiling. The only precaution to be observed is that the temperature of the food, when the extract is added, shall not exceed 150° F. (65° C.). This point is very easily ascertained, for no liquid can be tolerated in the mouth, even when taken in sips, which has a temperature above 140° F. (60° C.). If therefore the food is sufficiently cool to be borne in the mouth, the extract may be added to it without any risk of injuring the activity of the ferments.

Pancreatic Extract as an Addition to Nutritive Enemata.—Pancreatic extract is peculiarly adapted for administration with nutritive enemata. The enema may be prepared in the usual way with milk-gruel and beef-tea, and a dessert-spoonful of liquor pancreaticus should be added to it just before administration. In the warm temperature of the bowel the ferments find a favourable medium for their action on the nutritive materials with which they are mixed, and there is no acid secretion to interfere with the completion of the digestive process.

I have now had some experience in this method of alimentation, and have been satisfied with its success. In one case a patient suffering from postpharyngeal abscess, which entirely occluded the œsophagus, was nourished exclusively for a period of three weeks (until the abscess broke) on enemata of milk-gruel mixed with pancreatic extract.

III.

THE USE OF MALT, AND ESPECIALLY OF MALT INFUSION, FOR THE PREDIGESTION OF STARCHY FOOD.

(From 'The Practitioner,' December 1879.)

SUMMARY:—Various kinds of diastase—Conditions in which starch digestion is defective—Preparations of malt—Malt extracts—Malt infusion—Its mode of preparation, properties, and preservation—Note on the antiseptic properties of chloroform—Administration of malt preparations with food—Predigestion of starchy food—Liebig's method—The use of malt infusion—Clinical experience.

THE digestion of starch consists, as is well known, in its conversion into dextrine and sugar. By this change starch becomes soluble and diffusible, and thereby adapted for absorption from the alimentary canal. It is further known that this conversion is effected partly by the saliva and partly by the pancreatic juice, and that the actual agent of the transformation is a special ferment contained in these secretions. As regards saliva, the ferment goes by the name of ptyalin, and is held to be identical with the diastase of malt. The corresponding pancreatic ferment has not received a distinctive name; indeed, until recently it was not thought to be a separate body; it was rather supposed that the pancreatic juice contained a single ferment which possessed manifold powers, and was able at the same time to peptonise proteids, to emulsify fats, and to convert starch into sugar. It is now, however, ascertained that these several powers correspond to separate ferments. The question has, as yet, been scarcely raised as to whether the diastasic agents of the saliva of the pancreas, and of malt, are one and the same ferment, or whether there are not more than one, perhaps several, modifications, all capable of doing similar work. It may be regarded as probable, in view of certain recent observations, that the latter supposition will turn out to be correct.

As regards the pancreas, I have obtained evidence, which I need not here particularise, that its diastasic agent is a distinct body from that of saliva and malt. Until further inquiry it will be convenient to use the word 'diastase' as a common term, signifying an amylolytic ferment, that is to say, a ferment having the power of resolving the starch molecule into more diffusible bodies of the dextrine and sugar class; and we may conveniently designate diastasic agents according to their local source as malt diastase, salivary diastase, pancreatic diastase, and so forth.[1]

Before diastase can exercise its power the cellulose investment of the starch granule must be ruptured. This is accomplished for the human subject by the art of cooking. In boiling and baking the starch-granules break up under the combined influence of heat and moisture, and the liberated starch swells out enormously by imbibition of water into a mucilage or jelly-like mass. Unless starch is previously changed into this gelatinous state it is acted on very slowly by the diastasic ferment. It is a matter of capital importance, therefore, in the sick room, to make sure that gruels, puddings, and other farinaceous dishes prepared for the invalid are thoroughly cooked.

---

[1] These three by no means exhaust the list of local diastases. There is a diastase in the urine, in blood-serum, in the liver, and several other tissues of the body; indeed, diastase seems to be one of the most widely diffused of all the soluble ferments, both in plants and animals.

Having premised so much, I pass to the consideration of the means we possess of artificially aiding the digestion of starch in cases where that process is defective from deficient diastasic power in the saliva and pancreatic juice. Unfortunately, our knowledge of the defect which it is proposed to remedy is very incomplete. Something, however, we do know with fair precision. We know that in infants under three or four months old the saliva has but a feeble diastasic power. I have further ascertained the significant fact that the pancreas of suckling calves is inert on starch, and the inference is strong that the pancreas of the infant at the breast is in the same predicament. It is not probable that the diastasic power is wholly wanting in sucklings, seeing how widely this power is distributed; but it appears certain that it does not exist in sufficient amount to be available for the digestion of sensible quantities of starchy food.[1] This being so, it is obvious that farinaceous articles are unfit food for young infants unless artificial means are used to assist their digestion. With regard to older children and adults, we possess very little exact knowledge respecting defective secretion of salivary diastase, and none at all respecting defective secretion of pancreatic diastase. We may nevertheless pretty safely conclude that whenever the mouth is dry there is diminished supply of salivary diastase. In the febrile state, in advanced stages of most organic diseases, after alcoholic excesses, and in a multitude of morbid conditions of various kinds, the mouth is dry and the saliva is scanty; and it is reasonable to infer that we shall be doing an important service to our patients so suffering by remedying this defect by artificial means.

---

[1] The earlier opinion that the saliva of young infants was wholly wanting in diastasic power is not supported by recent researches. Both Schiffer and Korowin found that the secretions of the mouth of infants had a certain power of converting starch into sugar. Zweifel also found that the extract of the parotid (but not the submaxillary) glands of still-born children and of infants dying a few days after birth possessed this power, though apparently in feeble degree. Extract of the pancreas in the same subjects was found inert. (Zweifel, *Untersuchungen über den Verdauungsapparat der Neugeborenen*.)

In malted barley we have at command an unlimited supply of diastasic power, and it is not surprising that many eyes have been turned in this direction, and that many efforts have been made to utilise this resource as a means of assisting the digestion of starchy food when the supply of natural diastase is deficient. Of late renewed interest in the subject has been created by the introduction into pharmacy of a new class of malt preparations, which, under the name of 'malt extracts,' are now challenging the attention both of the profession and the public in a very prominent manner. It will be worth while to inquire into the real value of these preparations which have suddenly become so popular. The task is made easy by the opportune appearance of a valuable report on malt extracts by W. R. Dunstan and A. F. Dimmock, published in the *Pharmaceutical Journal* for March 9, 1879. There is also a simpler and cheaper preparation of malt, namely, the cold-water infusion, which I desire to bring under notice. This latter preparation has not yet been formally introduced into medical practice; but its diastasic action on starch has been minutely studied by Mr. O'Sullivan, and by Messrs. Brown and Heron, in an important series of papers published in the *Journal of the Chemical Society*.[1] I propose to say something about both these preparations.

Malt Extracts.—These articles are now manufactured on an enormous scale. No less than three limited companies exist whose sole business appears to be to make and sell malt extract. The best brands—those that appear to command our English market—are Corbyn's, Kepler's, Trommer's, and the variety called 'Maltine'; and the remarks I am about to make apply exclusively to these four articles, which may be regarded as practically identical in character and merit. Malt extracts are essentially infusions of malt concentrated by evaporation to the consistency of a thick treacle. In order to preserve the activity of the diastase, which is destroyed by a heat exceeding 170° Fahr., the evaporation is conducted at a low temperature, *in vacuo*, by the aid of costly machinery, and this accounts for the high price of these preparations. Malt extracts thus prepared are of a dark-brown colour, very thick and viscid, and possess an agreeable, sweetish taste. Chemically they consist (besides water) of about 70 per cent. of a variety of sugar called 'maltose,' 2 per cent. of salts, a varying quantity of diastase, and about 6 per cent. of nitrogenised compounds. The exact condition of the nitrogenised matter is not known. Some of it, no doubt, exists as albuminoid material, but this does not seem to be in true solution, for I find that when malt extract is diluted with three or four times its bulk of water a copious precipitate falls, and the supernatant liquor shows only slight traces of albumen when tested with nitric acid. From these facts it may be gathered that the value of malt extract as a food is but little more than so much syrup, and that the statements made on this point in the advertisements are ridiculous exaggerations. These preparations have, however, important uses as vehicles—especially as a vehicle for cod-liver oil—which they suspend in the most perfect manner, and render acceptable to some stomachs which cannot tolerate the oil in any other guise. But the proper medicinal value of malt extracts must be held to depend entirely on the amount of diastase which they contain, and in this respect I found that the four brands already named were highly active, but not all equally so.

---

[1] 'Contribution to the History of Starch and its Transformations,' by Brown and Heron, *Journ. of the Chem. Soc.*, Sept. 1879. The papers of O'Sullivan are published in the same journal for the year 1872 and subsequent year.

Malt Infusion.—The cold-water infusion of malt is an energetic diastasic agent, and trials of its action on various farinaceous gruels have led me to believe that it may with advantage be added to our list of malt preparations. I have adopted the following method and proportions as yielding a pharmaceutical preparation of convenient standard strength. Three ounces (or three piled-up table-spoonfuls) of crushed malt are thoroughly well mixed in a jug with half a pint of cold water. The mixture is allowed to stand over night—that is to say, for ten or twelve hours. The supernatant liquor is then carefully decanted off from the sediment and strained through two or three folds of muslin until it comes through fairly clear and bright. The above quantities yield about six ounces of product. Malt infusion thus prepared has a light-brown colour like sherry, a faint sweetish taste, and the odour of beer-wort. It is slightly acid in reaction, and its sp. gr. is about 1025. It is rendered cloudy by nitric acid, showing that it contains albumen. Its chief solid constituent is maltose, and it is rich in diastase. I was surprised to find that the action on starch of the above standard malt infusion was quite as powerful as that of average specimens of malt extracts. This shows that, in spite of all the precautions used in the manufacture of malt extract, an enormous amount of the unstable diastase is rendered inert and lost in the process of concentration.[1] Malt infusion is very prone to fermentation, and it must either be prepared fresh for each day's consumption, or means must be used to preserve it from decomposition. This may be easily accomplished by adding a few drops of chloroform to the infusion, and keeping it in a well-corked bottle.[1] If the

---

[1] This loss, I have reason to believe, depends on increase of acidity during concentration. The malt infusion has an acid reaction, and the

acid to which this reaction is due is not volatile. The proportion of acid, therefore, increases as evaporation proceeds. All acids, even organic acids, except in very minute proportions, are highly destructive to diastase.

[1] NOTE ON THE ANTISEPTIC PROPERTIES OF CHLOROFORM.—The antiseptic properties of chloroform have recently been brought up in Germany as something new (see *Lancet*, Dec. 20, 1890, p. 1343). It is, however, no novelty at all. I have used chloroform for the preservation of all kinds of organic liquids constantly for the past fifteen years, and have incidentally mentioned the fact in several of my published papers. I derived the hint from Claude Bernard's observations on the narcotic effects of ether and chloroform on vegetable organisms. The antiseptic power of chloroform, according to my observations, is suspensive, and not destructive. It acts really rather as an anæsthetic than as a true antiseptic. It does not kill bacteroid organisms and their spores; it only renders them dormant. It has, therefore, no permanent sterilising power, and is not adapted for the preparation of sterilised culture fluids in bacteriological experiments. In the case of milk, blood-serum, and urine, for example, chloroform when present in excess and in corked phials preserves these fluids perfectly; but when the corks are removed, and the chloroform is allowed to exhale, putrefactive changes set in just as if no preservative had been used. My experiments on the use of chloroform for the preparation of culture media were performed in the following manner:—Long-necked flasks were charged with milk, blood-serum, or other organic liquid, and a few drops of chloroform were added, taking care that more chloroform was used than the liquids could dissolve. The necks of the flasks were then tightly plugged with cotton wool and firmly corked. Treated and kept in this way the liquids remained unchanged. But if at the end of a month or six weeks the corks were withdrawn, while the cotton wool plugs were left undisturbed to prevent the access of fresh germs, the volatile chloroform soon escaped, and putrefactive changes, with abundant growth of bacteria, commenced in a few days, showing that the germs originally present in the liquids were not dead but sleeping.

At one time I used chloroform as a digestive antiseptic, but as my observations multiplied I discontinued the practice as being obviously taste and odour of chloroform thus communicated to the infusion be objected to, this may be obviated by pouring out the intended dose into a wide-mouthed wine-glass or a saucer two or three hours beforehand, and allowing the vessel to stand on the mantelpiece or other warm place. The chloroform soon flies off in vapour, and the infusion is restored to its original taste and smell.

Preparations of malt may be utilised for their diastasic property in two ways: either they may be *administered with a meal*, so as to perform their mission during and for a short period after the ingestion of the food, or they may be *mixed with the food beforehand* with a view to predigest the starchy matters before they enter the mouth. I shall consider these two methods separately.

1. *Administration of Malt Preparations with Food.*— The labels on the malt extract bottles usually direct one or two dessert-spoonfuls to be taken after a meal. This is obviously a bad mode of utilising the diastasic powers of the preparations. A meal is often a long affair: the earlier portions may be in full digestion before the final portions have passed the mouth, and it must be borne in mind that diastase is rendered permanently inert by the acid of the stomach, and that as soon as the meal is penetrated by the acid gastric juice the conversion of

futile. Chloroform must be present in considerable proportion to exercise an appreciable antiseptic or antifermentive effect, and it could not be safely introduced into the stomach in sufficient quantity for this purpose; besides, fermentive processes do not occur in the stomach with such speed or to such an extent as to disturb its function, except in cases of pyloric obstruction. This proposition seems to be proved by the observations recorded in the next section, p. 242. As to any effect of chloroform on intestinal putrefactive changes, as supposed by Salkowski and Kirchner, it is quite inconceivable that a substance so volatile and absorbable could, in the warm atmosphere of the body, survive to reach the small intestines in sufficient quantity to exercise any antiseptic influence.

starch is arrested, and no further progress is made therein until it starts afresh in the small intestine under the influence of the pancreatic juice. When a malt preparation is administered *after* a meal the dose is not properly mingled with the food, nor is it mingled at the right time. The better plan is to direct the patient to sip his dose of malt extract or of malt infusion, as the case may be, during the progress of the meal. The object in view is to supplement the action of the saliva, and the artificial substitute should, like the natural secretion, be mingled with the food in the mouth so that it may have due opportunity for the performance of its destined work before its energies are checked by the rising tide of the gastric acid. Malt extract is taken in doses of one or two dessert-spoonfuls diluted with water or milk. Malt infusion may be taken in similar quantities, and in the same way; or it may be added to the beverage which happens to be used with the meal, for it has little taste of its own. I may mention that malt extracts, from their syrup-like consistence and flavour, are suitable for spreading on bread or toast, or for sweetening any kind of farinaceous pudding, gruel, or porridge. An effectual commingling of the ferment with the food is thus ensured.

2. *Predigestion of Starchy Food by Malt Preparations.*—Some years ago Liebig pointed out with great force the advantage—or rather the necessity—of predigesting the starchy aliments given to young infants, and suggested a method of preparing a farinaceous 'food for infants' by an ingenious process which was designed to completely transform its starchy ingredients into dextrine and sugar before the food was administered to the infant. This proposal of Liebig's is historically interesting, as the first successful attempt to provide human beings with food not only previously cooked, but also previously

digested. Liebig's plan and principle is this: ground malt and wheat-flour are mixed together with a due quantity of milk and a little water to form a gruel. This mixture is heated over a very slow fire until it thickens, which occurs when the temperature approaches 150° F. At this temperature the starch granules swell out and burst, and the starch is gelatinised. At the same time the diastase is dissolved out of the malt, and acts energetically on the gelatinised starch. The gruel is now diligently stirred for some time without increasing the heat, until at length, from the conversion of the starch into sugar, it becomes quite thin and diffluent. It is then raised to the boiling point, and when cool is ready for use.[1] This method is easy to the chemist in his laboratory, who proceeds thermometer in hand. But it is otherwise when the operator is a cook or nurse, and the apparatus a saucepan and an open fire. The starch does not begin to gelatinise until the heat rises above 140° F. Below this point the granules remain intact—at least, for a long time—and the diastase cannot attack them in this state. On the other hand, should the temperature rise much above 160° F., the diastase is destroyed by the heat, and the starch conversion is arrested in mid-career. If, therefore, this narrow range of some 20° F. be overpassed on either side, the desired result is not fully attained; and to keep within this narrow range is too much for the rough chemistry of the kitchen. This is the reason why this admirably-conceived method has failed to obtain a more firm footing in the sick rooms and nurseries of this country.[1]

---

[1] Liebig also added a few grains of bicarbonate of potash, in order to render the product more exactly equivalent to mother's milk. This is a needless complication, and may be regarded as an example of Liebig's passion for chemical symmetry, and his habit of looking at physiological questions too exclusively from a laboratory point of view. The diastasic action goes on perfectly well without the alkali, whose presence is more likely to hamper than to assist the further stages of digestion in the stomach.

All the difficulties, however, disappear if, instead of using the crude malt, we use the standard malt infusion of which I have spoken. By this means Liebig's idea can be carried out to completion with perfect ease, and a much wider application can be given to it than seems to have been contemplated by its illustrious author. The mode of proceeding with the malt infusion is as follows:—A suitable gruel is prepared from wheat, or from oatmeal, groats, pearl-barley, arrowroot, or any other farina. The gruel may be made with water alone, or, as is more usual, with the addition of milk or some kind of meat broth. In either case the gruel should be well boiled, and strained to separate the lumps. When the gruel is cold, or at least sufficiently cool to be tolerated in the mouth, the malt infusion is added. One tablespoonful (well mixed therewith) is sufficient to digest half a pint of gruel. The action is very rapid; in a few minutes the gruel becomes thin from the conversion of the starch. When this point is reached the food is ready for use. The only precaution to be observed in the process is to make sure that the gruel is at least sufficiently cool to be borne in the mouth before the malt infusion is added. It is not of the least consequence if the temperature be below this point, for the transformation goes on just as well, though not so rapidly, when the gruel is cold as when it is warm; whereas too high a temperature endangers the activity of the ferment, which is rendered inert at 170° F. The product of the action of malt on starch is not cane-sugar nor grape-sugar, but maltose,[1] and maltose has very little sweetening power. This is the reason why gruel thus digested suffers little change of taste; so little, indeed, that the addition of it to milk or broth produces scarcely any appreciable alteration of flavour.

---

[1] Efforts have been made to evade these difficulties in some of the 'foods for infants' sent out by manufacturing druggists, but without much success; and some of the so-called improved methods are a good deal worse than the original plan.

Malt extracts are less suited than malt infusion for the predigestion of farinaceous aliments. Malt extracts have a somewhat strong sweetening power, and they communicate a dingy brown colour to the food; whereas the malt infusion adds neither adventitious taste nor colour. Malt infusion has also an enormous advantage in point of price. Malt extracts cost three shillings a pound—the infusion can be made for three farthings a pound. The trials I have made, in actual practice, of food thus predigested have been highly satisfactory.

Since the above paper was written I have had an extended experience of the use of malt infusion as an aid to the digestion of farinaceous food, and I can speak with confidence of its efficiency and agreeableness. Although inferior in diastasic power to an active pancreatic extract, malt infusion has the great advantage of not imparting to the food any unpleasant flavour; and its deficiency in strength is easily compensated by the use of larger doses, which is a facile point with a substance so bland and cheap. Malt infusion should be regarded as a household remedy. Crushed malt can be obtained at any provender shop, and the preparation of the infusion may be entrusted to the housewife or nurse. In the digestive and intestinal troubles of infancy, when milk cannot be tolerated, a strong gruel predigested with malt infusion mixed with an equal volume of beef-tea or other meat decoction, constitutes, as I have often proved, an exceedingly valuable resource.

---

[1] According to the observations of Brown and Heron, 100 parts of starch are transformed by malt infusion, when the reaction has reached its ultimate terms, into 80 parts of maltose and 20 parts of dextrine. (*Journ. Chem. Soc.*, Sept., 1879.) The products of the action of salivary and pancreatic diastase on starch are, according to Musculus and v. Mering, absolutely identical with those of malt diastase. (Maly's *Jahresbericht* for 1878, p. 49.)

SECTION IV

DYSPEPSIA

ON THE ACID DYSPEPSIA OF HEALTHY PERSONS.

(*Fifth Lecture of the Owens College Course.*)

SUMMARY:—General description—Symptoms—The acid residuum—Nature and source of the acid—Particular symptoms—Pain—Depression—Acid eructations and heartburn—Flatulence—Gastric cramp or paroxysmal pyrosis—Diagnosis of acid dyspepsia—Further incidents of acid dyspepsia—Treatment—By antacids—By provoking salivation.

THE dyspepsia of substantially healthy people may be broadly divided into the *atonic* form and the *irritative* or *acid* form. In the former there is defect of digestive power—that is to say, deficiency of gastric juice, and deficiency of muscular action in the stomach. In the latter there is an undue secretion or an undue accumulation of acid in the stomach, especially towards the later stages of digestion. The former, or atonic dyspepsia, scarcely merits the name of dyspepsia; it is rather an oligopepsia, or apepsia; it is a defect rather than a disorder of digestion, and is often painless. It generally constitutes a part of some general ailment or debility, and is met with in the anæmic and in persons of low vitality, with feeble appetite, and slender powers of taking food.

Acid dyspepsia, on the other hand, is often seen in persons of strong constitution and good health, who work hard, are never laid up, and who live as long and are as good lives as their non-dyspeptic brethren. This form of dyspepsia is apt to trouble those who lead studious or sedentary lives; but it is by no means uncommon among farmers and those who lead an open-air life, especially if they belong to gouty families.

Acid dyspepsia is often, perhaps generally, associated with undue sensitiveness of the stomach (gastrodynia); hence there is frequently a certain commingling of symptoms—of symptoms due to mere hyperæsthesia and of symptoms due to disorder of the digestive process. Neurotic and hysterical individuals, both male and female, are very liable to gastric pains; although their digestion may be normal, their 'neurotic centre,' if I may be allowed the expression, is in their epigastrium; and their symptoms imitate those of true acid dyspepsia. In these cases of 'false dyspepsia,' as they may be termed, there is generally much complaint of flatulent distension, with noisy demonstrative eructation of gas, but without any real excess of acid in the stomach.

The acid dyspepsia of healthy persons consists essentially in a tendency or predisposition of an enduring character, the tendency being towards a generation or accumulation of excess of acid in the later stages of gastric digestion. The tendency is more or less permanent, and lasts with many persons from youth to age. It is rare in boyhood and girlhood, and tends to diminish in old age. It prevails at its maximum during the flush of manhood, and is distinctly more common among men than women. To a certain extent acid dyspepsia may be regarded as an ill-directed vigour of digestive action, as is well illustrated by the following incident. A habitual dyspeptic, who regularly suffered from painful excess of acid after each meal, on one occasion partook of an unusually heavy dinner, which proved too much for his digestive powers. After some hours of discomfort the meal was expelled with violent vomiting. This attack was followed by marked prostration of the gastric powers. During the ensuing forty-eight hours there was a state of oligopepsia, with diminished appetite, but each meal was digested with perfect comfort and without the least excess of acid. At the end of two days the appetite and digestive vigour returned, and with their return came also the dolorous incidents of acid dyspepsia.

With most dyspeptics their trouble is not altogether continuous. They have their good periods and their bad periods. During their good periods they may for weeks or months go on digesting their meals with the same comfort as their more fortunate brethren. Then again for weeks or months their condition is one of almost incessant and severe suffering. It may even become serious, and lead to loss of appetite, inability to take a due quantity of food, and to consequent emaciation and loss of strength. But as a rule the dyspeptic, in spite of his torments, maintains his flesh and bodily vigour unimpaired.

Symptoms.—The subject of acid dyspepsia generally takes his food with appetite, sometimes even with voracity. The early periods of digestion are also generally easy and comfortable, but after a while there is felt a weight and aching at the pit of the stomach, which often increases to a severe pain. Then succeed a sense of fulness and tightness in the epigastrium, repeated and copious discharge of flatulence, with eructations of sour liquid into the mouth, and tendency to nausea or, more rarely, actual vomiting. These symptoms come on earlier after a light meal than after a heavy meal. After breakfast the symptoms often appear very speedily—in half an hour or an hour—whereas after dinner they are usually postponed for one, two, or three hours. In very sensitive dyspeptics a glass of sherry or a basin of soup will appear to 'turn sour' in fifteen or twenty minutes.

There is generally with dyspeptics of this class an impression that their digestion is abnormally slow. I doubt whether this is really so. I think that digestion in these cases is, often at least, hurried, and consequently imperfect; and that, after the main act of digestion is over, there remains in the stomach a large residuum of an acid mucus, mixed with remnants of food, chiefly composed of fatty matter. This sour mass seems difficult to dispose of; it lingers long in the stomach, and gives a feeling of unpleasant fulness and distension, which does not really correspond with any actual excess in the bulk of the gastric contents. At length, however, this residuum is got rid of, and the stomach becomes empty and at rest; the pain and discomfort wear off, and there is peace for the dyspeptic until after the next meal; then comes a repetition of the same events.

Not unfrequently the acid residuum is not entirely got rid of when the next meal-time arrives, and hence sour eructations may be experienced *immediately* on taking the new meal, confusing the symptomatology. In this case the sour mucus, for a short space of time, floats on the surface of the new meal, and the eructations are consequently acid to the taste; but presently it mingles with the meal, and the degree of acidity of the total gastric contents is thereby reduced (by dilution), and the eructations cease to be sour. Hence it is that the ingestion of a meal sometimes relieves the dyspeptic for a while; and this often happens with an accidental 'fit' of acid dyspepsia in persons who are not habitually predisposed thereto. They are cured, much to their surprise, by taking a full meal—the fact being that the new meal gives the surplus acid work to do—and so ends the attack.

The secondary or sympathetic symptoms associated with acid dyspepsia are sometimes very puzzling to the inexperienced, and apt to lead him astray in regard to their real nature. There are pains of a neuralgic character and abnormal sensations in various parts of the body —in the gums, in the head, in the bowels, or indeed anywhere—cold feet, flushings of the face, lassitude, abnormal sleepiness, palpitation of the heart, and so forth.

The Acid of Acid Dyspepsia: its Nature and Source.— Being myself subject to occasional periods of acid dyspepsia, in typical form, I have had several opportunities of examining the sour residuum which accumulates in the stomach toward the later stages of digestion. When this is thrown on a filter a perfectly clear pellucid acid liquor comes through, not containing any trace of organisms. The degree of acidity was found to vary through a considerable range. The results of analysis on six several occasions gave the following degrees of acidity, expressed in terms of dry hydrochloric acid (HCl) :—

0·15 per cent. HCl
0·26 per cent. HCl
0·28 per cent. HCl
0·30 per cent. HCl
0·31 per cent. HCl
0·36 per cent. HCl

These numbers indicate a considerable excess in degree of acidity of the gastric contents.[1] Pure gastric juice (human) is estimated to have an acidity of 0·2 per cent. HCl, but this is considerably higher than the actual acidity of the contents of the stomach during normal digestion. According to the observations of Richet on a young man with gastric fistula (made artificially for the relief of impassable stricture of the œsophagus), the mean acidity of the gastric contents during the entire period of digestion was 0·17 per cent. HCl. But the variations were very great, and oscillated between 0·07 per cent. HCl on the one side and 0·3 per cent. HCl on the other.[1]

---

[1] Reichmann found in cases of acid dyspepsia still higher degrees of acidity than those recorded above; namely 0·34 per cent. and 0·45 per cent. HCl. On the other hand, Dr. McNaught found lower degrees—ranging from 0·09 per cent. to 0·2 per cent. HCl.—*Medical Chronicle*, vol. i. pp. 420 and 330.

The nature of the acid in the sour residuum is not always the same. It seems to be a variable mixture of hydrochloric and diverse organic acids in varying proportions. The kind and proportion of the organic acids must depend mainly on the composition of the preceding meal. Lactic and butyric acids are probably the organic acids most commonly present. The latter is certainly often present, and can be recognised by its peculiar acrid smell and taste. The discrimination of the organic acids from hydrochloric acid, when both are present together in a solution containing proteid compounds, is very difficult; and the tests in vogue (shaking up with ether, tropæolin, and methyl-violet) are by no means trustworthy. As this point is of interest and under inquiry, I may relate how I convinced myself that the acid of the sour residuum of acid dyspepsia was not (in the sample examined) unmixed hydrochloric acid. In the course of my inquiries I had occasion to investigate the effects of acids on diastasic action; and I found that organic acids had considerably less inhibitory power on starch digestion than mineral acids of the same saturating equivalence. Now, on comparing the inhibitory effect of pure dilute hydrochloric acid with that of the acid contained in the sour residuum, it was found that for the same saturating equivalents hydrochloric acid had more than double the inhibitory power of the acid of the sour residuum.

---

[1] Richet, *Du Suc Gastrique*. Paris, 1878.

The *source* of the acid in acid dyspepsia has been much debated. I have long since come to the conclusion that it is exclusively derived from excessive secretion or accumulation of gastric juice, and not from any fermentive process. The sort of windy turmoil which goes on in the stomach of the dyspeptic has led observers too hastily to the analogy of vinous fermentation. A more precise examination of the incidents of acid dyspepsia lends no support to this view.

Fermentive processes, whether toruloid or bacterial, cannot, I think, take place in the stomachs of healthy persons to an extent sufficient to have a practical bearing; they can only take place to this extent in cases of pyloric obstruction or of chronic dilatation, when the food is detained in the viscus for a very long time—for twenty-four or forty-eight hours, or longer.

Fermentive changes are altogether too slow to account for the rapid development of acidity and flatulence in cases of acid dyspepsia. The two following experiments show how very gradual is the development of acid in bacterial fermentation:—

(*a*) Two ounces of the sour eructation from a typical case of acid dyspepsia were carefully neutralised with caustic soda, and then set aside in the warm chamber at blood-heat. After four hours only the feeblest acidity —amounting to 0·018 per cent. HCl—was developed. Bacteria were found under the microscope in scanty numbers, evidently only beginning to swarm.

(*b*) Two fluid drachms (7 cubic centimeters) of the same sour eructation were mixed with twelve ounces (340 cubic centimeters) of warm bread and milk. The whole mixture was now faintly acid=0·012 per cent. HCl. In two hours the acidity had not appreciably altered. In five hours the acidity had increased to 0·015 per cent. HCl, and at the end of twenty-four hours (during the whole of which period the mixture had been maintained at blood-heat) the acidity had only risen to 0·035 per cent. HCl. In neither case was there any appreciable production of gas. The presence of organic acids in the acid residuum is easily accounted for without calling in aid the agency of fermentation. For, as has been explained in a previous lecture, salts of the organic acids, present in the articles of food, are decomposed by the hydrochloric acid of the gastric juice—chlorides of the bases are formed, and the organic acids are set free (*see* ante, p. 145). In this way the occurrence of lactic, butyric, tartaric, malic, and other organic acids in the sour residuum is easily and naturally accounted for.

Particular Symptoms.—The most common and characteristic symptoms of acid dyspepsia are *pain*, *depression*, *acid eructations and heartburn*, *flatulence*, and *gastric cramp or paroxysmal pyrosis.* To each of these symptoms I propose to devote a few words.

Pain.—The dolorous sensations about the epigastrium, which often extend upward to the lower sternal regions, are essentially due to the irritating action of the acrid and acid residuum on the mucous membrane of the stomach. This is the main and true explanation of the pain. But in the subjects of acid dyspepsia, especially during their bad periods, the stomach is unusually sensitive; and a residuum which would not be felt during their better periods, nor in non-dyspeptics, causes acute sensations. The severity of the pains (apart from varying sensitiveness of the stomach) depends (*a*) on the degree of acidity; the sourer the residuum is, the greater is the smarting caused by it; (*b*) on the proportion of butyric acid contained therein; for butyric acid is much more acrid than so much lactic or hydrochloric acid; (*c*) on the quantity or volume of the residuum. If the quantity be small—only one or two ounces—there may be no pain though the acidity be high; on the other hand, if the residuum be large it may cause pain though its acidity be not excessive; because the extent of mucous surface brought into contact with the irritating fluid affects the degree of sensation produced. Just as with the impression of hot water on the skin, the dolorous sensation varies proportionately to the extent of surface exposed; the finger can easily tolerate immersion in water at a degree of heat which would be quite unbearable to the whole arm.

During the bad periods the pain and aching at the epigastrium linger after the stomach is empty, so that the discomfort is almost continuous.

Depression.—There is often a pronounced sense of depression. In neurotic individuals this is spoken of in exaggerated language. It is described as a horrid torment; they say that their life is made miserable, and not worth living. This constitutes what has been known of old as hypochondria. The pain and physical discomfort in the epigastrium appear to me quite sufficient to account for this depression, without invoking the aid of any poisonous alkaloid, formed during the digestive process. There is a peculiar bitter principle, produced during both the gastric and pancreatic digestion of proteids;[1] but this is a normal product, and there is not the least evidence that it possesses poisonous properties.

---

[1] I called attention to the production of this bitter principle in my Lumleian Lectures (*see* ante, p. 195).

Acid Eructations and Heartburn.—These are usually prominent symptoms of acid dyspepsia, but are not invariably present. There is a regurgitation into the mouth of sour liquid from the stomach with discharge of flatulence. The savour of the eructation may be simple sourness, like that of lactic or hydrochloric acids, but often it has a burning, acrid quality—this occurs when butyric acid is contained in the residuum. Butyric acid is volatile, and rises in acrid fumes, which affect the cardia and œsophageal orifice of the stomach and cause a persistent feeling of heat and horrification, with a nauseating tendency. This constitutes true heartburn. The occurrence of heartburn with the presence of butyric acid requires no intervention of butyric fermentation to explain it. Milk, butter, cheese, and other fatty food, all contain more or less butyric acid, either free or in combination. The butyrates are decomposed (as previously explained) by the hydrochloric acid of the gastric juice, and butyric acid is liberated in the free state. But how, therefore, it may be asked, is not heartburn a more constant incident of acid dyspepsia? The reason probably is, that to produce a sensible quantity of butyric acid the butyrates must be present in the meal in considerable amount, as in rancid butter and other rancid fats often used in cooking, and secondly that the acid in excess must be hydrochloric acid, and not merely lactic or other organic acid—otherwise the butyrates are not decomposed—and the proportion of mineral to organic acid in the sour residuum varies a good deal.

Flatulence.—This is an invariable accompaniment of acid dyspepsia. The accumulation of gas in the stomach causes a sense of fulness and distension and an importunate desire to get rid of the accumulation by upward discharge. This importunity is intensified by the hypersensitiveness of the stomach, which is impatient of an amount of gas which would not incommode it, nor require upward discharge, but would be otherwise disposed of, perhaps through the pylorus, if the stomach were less sensitive. The occurrence of butyric acid also aggravates the gastric discomfort. The vapour of this acid, when it is largely present in the residuum, must be always rising into acrid fumes in the warm atmosphere of the stomach. But apart from hypersensitiveness of the organ, and apart from the vapour of butyric acid, there is undoubtedly an abnormal generation or accumulation of gas in the stomach in acid dyspepsia. What is its source? The fermentation theory, as already explained, is wholly inadequate to account for it, and we are driven to other modes of explanation. My impression is that the accumulation of gas in acid dyspepsia may be traced to three sources. (*a*) *Swallowed air*. There is a large amount of air entangled and swallowed during the deglutition both of food and of saliva. The air engulfed with food is not larger in acid dyspepsia than in non-dyspeptics, but in regard to that swallowed with saliva there is a difference. During the existence of excess of acid in the stomach there is a certain amount of unconscious salivation going on, and a larger amount of air is thereby carried down than in the normal state. (*b*) *Liberation of carbonic acid in the stomach.* The saliva secreted during the period of surplus acid in the stomach is much more alkaline (from carbonate of soda) than when the contents of the stomach are neutral or only moderately acid. I have found this to be constantly the case; sometimes the alkalescence of the saliva is so high as to occasion visible effervescence on the addition of an acid. When the stomach is empty and neutral the saliva then secreted barely turns the colour of litmus paper, but when the organ contains excess of acid I have found the alkalescence of the saliva equal to 0·04 per cent. HCl. When this alkaline saliva, secreted in unusual profusion, descends into the stomach, it encounters the acid residuum, and is neutralised thereby with liberation of a certain amount of carbonic acid. I shall return to this point when I come to the treatment of acid dyspepsia. (*c*) *Regurgitation of carbonic acid from the duodenum.* This is a third probable source of gas in the dyspeptic. When the chyme passes through the pylorus it encounters the secretions of the liver and pancreas, both of which are alkaline from carbonate of soda. The collision must liberate carbonic acid. We may regard it as probable that when the contents of the stomach are super-acid the biliary and pancreatic secretions are, as in the case of the saliva, super-alkaline, and that consequently a larger disengagement of carbonic acid occurs in the duodenum under such conditions than in tranquil digestion. The gas thus generated would unduly distend the duodenum, and would probably push its way partly upwards through the pylorus into the stomach, and partly downwards into the jejunum.

It has been suggested, as a partial source of gas in acid dyspepsia, that carbonic acid is exhaled from the blood through the mucous membrane of the stomach (as in the process of respiration through the pulmonary membranes), but I do not see why this should occur in a larger degree in dyspeptics than in other healthy persons. I can, however, easily believe that in regurgitant heart disease and in general emphysema, when there is severe venous stasis in the stomach, and a cyanotic state of the blood, such exhalation of carbonic acid through the gastric mucous membrane may take place, and that this accounts for the distressing flatulent distension which is so common in these affections. But in acid dyspepsia the blood is not surcharged with carbonic acid, and there is no venous stasis in the stomach.

Gastric Cramp or Paroxysmal Pyrosis.—The course of acid dyspepsia is sometimes diversified by the occurrence of a very peculiar and characteristic symptom, which, though brief in duration, is very distressing, and even alarming to the uninitiated. This symptom consists in a paroxysm, of which the chief features are sudden cramp of the stomach with sudden profuse salivation. The attack only lasts half a minute or a minute, but to the sufferer the time appears long. I would suggest that the word *pyrosis* be confined to these essentially paroxysmal attacks. Writers on dyspepsia exhibit confusion in the use of the term pyrosis, and give it a mixed description, which includes partly these paroxysms and partly the ordinary symptoms of acid dyspepsia and heartburn. The gush of saliva into the mouth is often misunderstood, and is described as a regurgitation from the stomach or from the lower part of the œsophagus.

Paroxysmal pyrosis is essentially an abortive and incomplete act of vomiting. Complete vomiting consists of the following succession of events:—Gastric spasm, profuse salivation, convulsive spasm of the abdominal muscles, sudden downward thrust of the diaphragm, closure of the glottis, opening of the cardia, and finally ejection of the contents of the stomach. The abortive act which constitutes a paroxysm of pyrosis falls short of the complete act in the absence of the downward thrust of the diaphragm, and of the opening of the cardia; moreover, the contraction of the abdominal muscles is either absent altogether or is cramp-like rather than convulsive; the voice is reduced to a whisper, but is not altogether suppressed, so that the closure of the glottis is not absolute;

and there is no ejection of the contents of the stomach. Occasionally, however—but this is quite exceptional—the paroxysm does culminate in actual vomiting. The sense of nausea is imperfectly developed in these attacks. The gush of saliva is something tremendous—often greater than incessant swallowing efforts can dispose of—and the surplus flows out abundantly from the mouth. Some persons are not conscious of swallowing any of it, and believe that they let it all flow out at the mouth. A paroxysm of this kind only occurs during the presence of surplus acid in the stomach, and on its conclusion there is a sensible relief (for a time) to the previously existing epigastric pain and other symptoms of acid dyspepsia.

I have had several opportunities of examining the fluid that gushes into the mouth in paroxysmal pyrosis, both in my own case and in that of patients. It invariably possesses the character of true saliva, differing only in its unusual degree of alkalescence. I will give two examples. The first is from my own person. During a typical attack of gastric cramp I succeeded in collecting some of the fluid which flowed in an abundant stream into the mouth. Its alkalinity was equal to 0·125 per cent. HCl; it effervesced distinctly with acid. In diastasic power it was more active than average healthy saliva—in the proportion of 12 to 8. The second example was from a patient who was subject to recurrent and severe attacks of paroxysmal pyrosis. On closely questioning this patient he insisted that the fluid which came into, and flowed out of, his mouth during the paroxysms came from the stomach. He was quite sure that it was not a rush of fluid into the mouth from the sides of the mouth itself. I requested him to send me on the next occasion some of the ejected fluid in a bottle.

He did so. I found it, as I had expected, to possess all the properties of true saliva, with excess of alkali. Its alkalinity was equal to 0·15 per cent. HCl, which corresponds very closely with the grade of acidity of the gastric contents during tranquil digestion. Its diastasic activity was fully equal to that of fresh normal saliva, as tested by standard starch mucilage in the manner previously described (*see* p. 114).

I cannot therefore doubt that the gush of fluid in paroxysmal pyrosis is purely and exclusively a gush of saliva.

The relief which commonly follows a paroxysm is obviously due to the large quantity of alkali introduced into the stomach with the gulped saliva.

The paroxysms of pyrosis occur quite irregularly—rarely more than once in one day, more generally once in two or three days, sometimes only once a week, or once a month, or even once a year. Some dyspeptics never experience these paroxysms. They occur exclusively during the presence of excess of acid in the stomach, but they are not infrequently provoked by an impression of cold, or a chill.

Diagnosis of Acid Dyspepsia.—The diagnosis of acid dyspepsia is in principle perfectly simple. If the dolorous sensations at the epigastrium are relieved by a dose of carbonate of soda, or any other alkali, the case is one of acid dyspepsia. Such a dose, as habitual dyspeptics know well, infallibly gives relief. The relief may not be quite complete, but it is always marked and speedy. If no such relief is given the case is certainly not simply one of acid dyspepsia. In neurotic and hysterical individuals the diagnosis is not always so easy, because such persons give a confused, often discrepant, account of their sensations, and are poor subjects for this kind of crucial experiment.

When the dyspeptic takes a dose of soda early after a meal the relief is only temporary, and does not serve until the next post-cibal emergency; but if he takes his dose later on the relief lasts until after the next meal, and the subsequent eructations are perceived to have lost their sour and acrid taste.

Further Incidents of Acid Dyspepsia.—Slight meals are sometimes more provocative of acidity than full ones. A meal taken at an unusual hour, or a full meal eaten at an hour when usually a light meal is taken, is also very apt to provoke acidity. Surplus acidity is provoked by anything that renders the meal more difficult of digestion, such as imperfect mastication or hurried eating. As a rule, careful 'dieting' is of no avail, or only of partial avail, in acid dyspepsia. Constipation of the bowels distinctly intensifies the symptoms. Almost all habitual dyspeptics have their special lædantia and juvantia, and to none is the old proverb more applicable that 'one man's meat is another man's poison.' Some cannot take sugar, others can take it freely; the same with eggs, with soup, with various wines and beer, with tea, coffee, some kinds of meat, with potatoes, and so forth. Fatty matters disagree very generally. The dyspeptic stomach is peculiarly capricious and peremptory, and, as a rule, there is very little use in arguing with it in regard to its likings and dislikings.

The appetite is usually good; dyspeptics often enjoy their meals and 'could eat more' were it not for fear of the consequences. Sometimes the appetite is voracious; sometimes, on the contrary, the appetite is weak or capricious.

Treatment.—The treatment of cases of habitual acid dyspepsia divides itself into—(*a*) means which are directed to obtain relief from present discomfort; and (*b*) means which aim at curing the disorder, or at least at shortening the bad periods. The bias or tendency is, as I have before remarked, more or less enduring; but if you can cut short the bad periods, this is nearly as good as complete cure, because the ailment can thereby be controlled and, practically, nullified.

(*a*) *Treatment by Antacids.*—For immediate relief there is nothing better than a dose of carbonate of soda. Five or ten grains of bicarbonate of soda dissolved in water almost at once allay the suffering by saturating the gastric acid. A copious upward discharge of carbonic acid follows such a dose. Other alkaline substances are equally effective—magnesia, chalk, or carbonate of potash. But by far the most advantageous mode of administering antacids in these cases is in the guise of the lozenge. A lozenge properly used should be deliberately sucked, and not roughly chewed and swallowed. The process of sucking induces a plentiful flow of alkaline saliva, and the presence in the stomach of this bland demulcent secretion is soothing to the angry mucous membrane. The compilers of the *British Pharmacopœia* have provided us with two, and only two, antacid lozenges—namely, the *troch. sod. bicarb.* and the *troch. bismuthi.* The former contains 5 grains of bicarbonate of soda in each lozenge. It is an effective antacid, but it is not a favourable example of pharmaceutical art. It has a peculiar nasty, soapy taste, which makes the sucking of it a penance; and this, I presume, is the reason why it has not become popular with dyspeptics. The bismuth lozenge is in every way a better article. It owes its antacid properties to 3½ grains of chalk and 2½ grains of carbonate of magnesia. These quantities are, in saturating power, equal to 10 grains of bicarbonate of soda. This is a full antacid dose, and the chalk and magnesia are practically tasteless, and this is a distinct advantage in regard to the active ingredients of a lozenge. The subnitrate of bismuth, to which this lozenge owes its name, has no antacid properties, and is probably inert. It imparts, however, a slight metallic taste, and communicates to the breath a somewhat disagreeable taint; so that its presence in the lozenge may, I think, be regarded rather as a tribute to the decaying art of polypharmacy than as a really useful addition. The bismuth lozenge has won its way into favour with dyspeptics by sheer merit, and inquiries which I have caused to be made among druggists and lozenge-makers show that the sale of this lozenge is steadily and largely increasing all over the country. A bismuth lozenge without the bismuth would be a nearly perfect antacid lozenge, and I would venture to suggest that some such lozenge should be introduced at the next revision of the *British Pharmacopœia*.[1]

Besides these officinal articles, there are largely sold in the shops a variety of lozenges and tablets for the use of dyspeptics. None that I have examined fulfil the conditions of a perfect antacid lozenge. The compressed tablets of carbonate of soda and the soda-mint tablets, although effective as antacids, are so unpalatable that they cannot be properly sucked without disgust, and, indeed, those who use them generally swallow them whole in haste—and thus miss the concurrent flow of saliva, which is distinctly helpful to dyspeptics. Some of the antacid lozenges sold in the shops are flavoured with pungent spices to conceal the taste of the soda. All such adjuncts are obviously a mistake. Pungent spices have a strong tendency to provoke acidity in the stomach; and, moreover, any pronounced flavour is objectionable in an article which is used frequently. The alkaline salts of the Vichy springs have been made into very agreeable lozenges, which are sold in this country in sealed boxes. They owe their antacid properties chiefly to carbonate of soda, but partly also to carbonate of potash and to the carbonates of lime and magnesia. They contain besides a small quantity of sodium chloride, which pleasantly sharpens their flavour. These lozenges have a comparatively feeble saturating power, but owing to their full sapid qualities, they provoke an abundant flow of alkaline saliva, and this renders them effective for the relief of gastric acidity. Were it not for their costliness, I believe these Vichy lozenges would soon get into favour with dyspeptics.

---

[1] This suggestion has been carried out by several manufacturing druggists. Some have added 1 grain of sodium chloride to each lozenge; this addition pleasantly sharpens its flavour, but has the disadvantage of rendering the lozenge hygrometric in very damp weather.

As to the comparative merits of the several antacids employed in acid dyspepsia, there is, perhaps, on the whole not much to choose. Certain differences may, however, be noted. The alkaline bicarbonates have a nauseous taste, and if taken in excess they leave an alkaline residuum in the stomach. This is at least abnormal, and perhaps embarrassing, in an organ which requires the presence of an acid to perform its functions. The earthy carbonates, on the other hand, are tasteless, and, owing to their insolubility, they cannot, when taken in excess, cause the neutral line to be over-passed. Perhaps the most advantageous course would be to vary and change the antacid from time to time.

The question may now be put—Is there any harm in the practice of habitually using antacids for the relief of acid dyspepsia? Do dyspeptics purchase present ease at the cost of some future detriment? My attention has been directed to this point for some years. I have, naturally, regarded a practice so artificial with considerable misgivings. But the more extended my experience has become the more I have been satisfied that, with due precautions, the practice is harmless—and I know of no valid evidence from any other quarter to justify a contrary conclusion. My own experience has been mostly gained from the use of the bismuth lozenges, which I have largely prescribed for a considerable length of time. I have, however, invariably enjoined the following strict rules in regard to their use:—They were not to be used at or near meal times—not sooner than three-quarters of an hour or an hour after breakfast, nor sooner than an hour or an hour and a half after dinner; they were not to be used regularly and systematically, but only as the occasion arose—that is to say, when gastric pain was distinctly present, and was producing more discomfort than a man could be reasonably expected to bear who had the easy means of relief ready to his hands; lastly, the use of the lozenges was to be discontinued if their employment did not cut short the pain. This last injunction leads up to the remark that an antacid dose is sometimes a useful means of diagnosis in cases of gastralgia. It is often impossible to decide from a patient's statements what may be the real nature of the pains complained of. In such a case, if an effective antacid does fail to give relief, it is sure evidence that the pains are not due to gastric acidity.

A useful notion of the relative antacid potency of the several articles in common use as gastric antacids (as sold in the shops) may be obtained from an inspection of the following table. Ten grains of bicarbonate of soda are taken as a standard antacid dose; and the quantities given of the other articles correspond in saturating value to this standard dose. The results were obtained by direct alkalimetrical determinations, and are here shown in round numbers :—

Table of Antacid Equivalents.

10 grains sod. bicarb. = 12 grains pot. bicarb.
„ „ „ = 6 „ creta precipit.
„ „ „ = 6 „ carb. magnesia.
„ „ „ = 3 „ light calcined magnesia.
„ „ „ = 6 fluid ounces lime water.
„ „ „ = 2 fluid drachms liq. potassæ.
„ „ „ = 1 bismuth lozenge *B.P.*
„ „ „ = 2½ Wyeth's soda-mint tablets.
„ „ „ = 5 Vichy lozenges.

Treatment by provoking Salivation.—The use of antacids, although adequate for immediate relief, has not much permanently beneficial effect in cases of habitual acid dyspepsia. The symptoms are apt to return with unabated severity after the next meal. It seemed, therefore, desirable to find some more curative method than that of exhibiting endlessly recurrent doses of alkaline substances. Having found that during the prevalence of surplus acid in the stomach there coincided an increased flow of saliva, and that this saliva possessed an unusual degree of alkalescence, I was led to the idea that the saliva was the natural antacid of the stomach. On several occasions I was able to measure synchronously the alkalinity of the saliva and the acidity of the stomach; and I found that the proportion between them was such that six to eight volumes of the saliva would saturate one volume of the gastric acid. There does not, at first sight, appear to be much prospect of relief from this small proportion of salivary alkali. Nevertheless, when it is considered that complete saturation of the gastric acid is by no means necessary to procure relief, and that all that is required is that the acidity should be so reduced as to bring it within the limits of the normal acidity in tranquil digestion, the prospect looks much more promising. If the acidity in the stomach could be reduced one-fourth or one-third, these normal limits would be usually attained. And I think it highly probable that, in the usual course of events in acid dyspepsia, the descending stream of alkaline saliva does fulfil an important purpose. When the stomach contains an excessive quantity of sour residuum we may suppose that the pylorus is closed against its passage into the duodenum. This may be regarded in the light of a conservative act, and designed to prevent disturbance of the alkaline digestion in the duodenum by an overwhelming influx of acid from the stomach. But by the steady, continuous downward flow of alkaline saliva the excessive acidity in the stomach is gradually lessened, and at length brought down to the normal grade, and then the refractory pylorus opens, and the stomach is relieved.

This train of ideas led me further to the notion that if the flow of this alkaline saliva could be increased, effective relief might thereby be given in acid dyspepsia, and that by acting in this way we should be operating more closely after nature's indications than by giving alkalies of extraneous source. We should be making the blood itself the source of the alkali, instead of taking it from the shop. And on trial I found the results conformable with the theory. Anything that increased the flow of saliva was found to abate the pangs of acid dyspepsia. Lozenges of all sorts promote a flow of saliva, but especially lozenges which contain a stimulating ingredient like ginger or cayenne. A very sensible relief is given to the dyspeptic by the use of these lozenges ; and this is probably the secret of the habit of some country dames, who carry in their capacious pockets a root of ginger, to which they apply when the stomach aches. A step further led me to the use of simple gum-lozenges.

The sucking or chewing of any kind of lozenge will promote salivation; the turning round with the tongue, and the mastication of the little morsel, sets the salivary glands to work. Lumpy 'tears' of gum arabic, such as may be picked out from the druggist's stock, do not make bad lozenges for this purpose. The 'glycerine jujubes' of the shops likewise consist of nearly pure gum, and these are somewhat more palatable than the gum tears, and answer equally well, or better, as provokers of salivation. The sugar contained in them is, however, objectionable to some stomachs. I think a lozenge composed of gum, with the addition of a little pyrethrum, might be a valuable addition to the resources of the dyspeptic.

By the use of lozenges, and especially of gum lozenges, I have obtained in the treatment of acid dyspepsia distinctly more curative results than by the use of alkalies. The advent of the bland gummy solution in the stomach probably acts topically as a soothing application to the irritated mucous membrane, allays its abnormal sensitiveness, and thereby disposes it to a more normal performance of its functions in dealing with the succeeding meal. If the surplus acid is great, and the torment severe, a dose of alkali must be administered; but the milder means here suggested will give adequate relief in many instances, and will greatly promote the abbreviation of the bad periods.

With regard to the regulation of the diet of the dyspeptic, the removal of habitual constipation, the due mastication of the food, the avoidance of hurried eating, the use of exercise in the open air, and the adoption of other hygienic precautions, I have nothing to add to the rules laid down on these matters in your manuals and in special treatises on dyspepsia.

APPENDIX

THE OPIUM HABIT IN INDIA

82

THE OPIUM HABIT IN INDIA

A MEMORANDUM ON THE GENERAL FEATURES AND THE MEDICAL ASPECTS OF THE OPIUM HABIT IN INDIA.

The following 'Memorandum' was prepared by the author when serving as a member of the Royal Commission on Opium, and is printed in the Blue-book as an 'Annexure' to the Official Report of the Commission—issued in 1895.[1]

It is republished with the permission of the Controller of H.M. Stationery Office.

It seemed advisable for several reasons that the large mass of new and interesting information, gathered by the Opium Commission during their tour in India, on the general features and the medical aspects of the opium habit in that country, should be analysed and digested somewhat more fully than was possible to do in the body of their official Report. This task naturally fell to my share, as the only medical member of the Commission.

---

[1] The Royal Commission on Opium was appointed in 1893. It consisted of:—Lord Brassey (chairman), Sir James B. Lyall, the Maharaja of Darbhanga, Mr. Haridas Veharidas, Mr. Henry J. Wilson, M.P., Sir William Roberts, M.D., Mr. R. G. C. Mowbray, M.P., Mr. A. U. Fanshawe, and Mr. Arthur Pease, M.P. The Commission was instructed to report on certain questions relating to the production and sale of opium in India—and also on 'The consumption of opium by the different races and in the different districts in India, and the effect of such consumption on the moral and physical condition of the people.' It was especially in response to this particular clause of the order of reference that the present Memorandum was drawn up. The Commission, after holding several sittings for the examination of witnesses in London, proceeded to India, where they spent nearly four months of the cool season 1893–4 collecting evidence in different parts of that country, visiting in succession Calcutta, Patna, Benares, Lucknow, Umbala, Lahore, Delhi, Agra, Jeypore, Ajmeer, Indore, Ahmedabad, and Bombay. A section of the Commission (including myself) visited Burma, and held sittings at Rangoon and Mandalay. The materials used in the preparation of this

The matters requiring examination are considered under the following headings:—(1.) The non-medical use of opium, or the opium habit proper. (2.) Opium as a household remedy. (3.) Opium as a prophylactic against malaria. (4.) The custom of giving opium to infants. (5.) The use of opium on occasions of ceremony. (6.) Opium smoking in India.

The consumption by all human communities, except the most primitive, of one or more articles of a stimulating and restorative character—such as alcohol, tobacco, opium, tea, coffee, cocoa, Indian hemp, betel, and others—constitutes a remarkable feature in the natural history of man. A practice so widespread and general must correspond to some profound instinct of human nature. These articles do not possess, in their essence, nutritive properties, and they are not classed as true articles of food, though some of them are largely used with the daily meals. Numerous individuals, and even considerable classes, forego their use, either wholly

---

Memorandum were nearly all drawn from the Minutes of Evidence and the papers and documents consigned to the Commission—all of which are printed with the Official Report of the Commission, forming seven volumes of Blue-book. Where other material has been used, its source is indicated in foot-notes. I may add that complete copies of the Report of the Opium Commission, together with the voluminous Minutes of Evidence and the papers and documents referred to, have been deposited in the libraries of the following institutions:—The Royal College of Physicians, London; The Royal College of Surgeons of England; The Royal Medical and Chirurgical Society, London; and the *Owens* College, Manchester.

or in part. These substances cannot, therefore, be regarded as necessaries of man's animal life. And the inference would seem to be that their use is connected in some subtle way with the play of those faculties and feelings which are peculiar to man as a social and self-conscious creature.

Whatever collateral use, dietetic or other, the substances in question may have, it is certain that the essential purpose for which they are taken is to modify, in a favourable[1] sense, the action of the nervous system. And although this modification varies, both in kind and degree, with each particular article, it is nevertheless true that all of them, when legitimately used, produce a certain community of effect on the user. This common effect, in its broadest and most general experience, may be described as an enhanced sense of well-being, or 'euphoria.' On the ground of this common action these substances may be conveniently united together into one natural group of (non-nutrient) physiological agents, and designated 'euphoric' agents.[2]

(1.) The Opium Habit in India.

Opium was first introduced into the East, no doubt, as a medicine; and its use as a stimulant and restorative was engrafted upon and grew out of the medicinal use. And it is still probably true, as regards India, that the larger part of the opium consumed in that country is used for the mitigation of suffering and the prevention and cure of disease. These two uses of opium—the medicinal and non-medicinal (or euphoric)—although in principle distinct, are in practice often so merged together and interfused as to be indistinguishable. This composite character of the opium habit is a constant source of confusion with incautious observers, and effects are attributed to opium which are really due to concomitant disease. In what follows it must be understood that in speaking of the opium habit in India the practice of eating or drinking opium is always meant, and not the practice of smoking opium, which is separately dealt with.

---

[1] That is, 'favourable' as judged by the sensations of the user.

[2] The words euphoria and euphoric are not new. Euphoria is an old medical term, signifying 'feeling perfectly well and able to bear pain and anxiety easily.' These words are again creeping into use both here and on the Continent. Levinstein employs the word euphoria in his work on the morphia habit (*Morphiumsucht*, p. 6), and the adjective euphoric (*euphorische* Wirkung) is used by Erlenmeyer in his treatise on the opium habit (*Opiumsucht u. ihre Behandlung*, 3rd ed. p. 11). Some such words are much wanted. Their adoption would save circumlocution, and give greater precision to language in speaking of the primary and common effect of alcohol, opium, tobacco, tea and coffee and their congeners.

Among the substances employed by mankind as exhilarants and restoratives, opium takes a position intermediate between alcohol and tobacco, and it may be compared and contrasted with both. All three tempt to excess, and require, in a good many of their votaries at least, the wholesome exercise of self-restraint to prevent injurious consequences. Opium, like alcohol, is greatly restricted in its geographical range by conditions of climate and race, whereas tobacco is equally at home in every climate and with every race. On the other hand, opium is more akin to tobacco than to alcohol in the large part played by personal idiosyncrasy in determining its diffusion through a community. Opium and tobacco are also alike in not producing in their users any special organic tissue changes, even when carried beyond the verge of moderation; whereas alcohol, if used in habitual excess, produces special organic changes by which its operations can be tracked, both during life and after death.

Distribution and Prevalence. — The opium habit is disseminated all over India, and through all classes of society—but very irregularly, according to climate, locality, race, caste, and religion. It is difficult to form a reliable estimate of the proportion of opium-eaters in a community. The habit is, by its nature, cryptous and undemonstrative. The consumers carry with them, hidden in the folds of their garments, small pieces of opium or little boxes containing opium pills. The dose is taken without show; it neither taints the breath nor colours the saliva. Servants in domestic or personal service may practise the habit for long years without awaking any suspicion on the part of their employers that they are opium-eaters. For this reason the estimates given of the ratio of opium-eaters to population must be taken with great reserve, and considered as rough guesses rather than as precise statistical data.

A few of these estimates may be cited as showing their great disparity. In the district of Balasore, in Orissa, Dr. Vincent Richards estimated the opium-eaters as forming 7 to 8 per cent. of the adult population. Mr. Driberg rated opium consumers among the native Assamese as 30 to 35 per cent. of the adult males, and among the Mikirs (a tribe in Assam) as 80 to 85 per cent. Dr. O'Brien calculated the opium-eaters of Burdwan as only 5 per cent. of the adult males. Dr. Juggo Bundo Bose, a Native physician at Calcutta, reckoned that not more than 2 per cent. of the adult males among his countrymen habitually consumed opium. Another witness from the same quarter estimated the number as 5 or 6 per cent. Dr. Cobb judged that some 3 to 5 per cent. of the whole population of Dacca in Eastern Bengal were opium-eaters; this would correspond to about 12 to 20 per cent. of the adult males. The Marwaris, a caste of enterprising merchants from

Marwar in Rajputana, but scattered all over India, are large consumers. According to Dr. Harvey the 'majority' of them are opium-eaters. Dr. Hall, speaking from his experience in the North-Western Provinces, estimated that one half of the elderly men were habitual eaters. The most precise estimate laid before the Commission was that of a Zemindar, whose estates lay in the Bengal Presidency. He stated that in his native town of Uttarpara, containing somewhat over 6,000 inhabitants, there were 821 opium-eaters. A Native medical practitioner of large experience at Benares said that in that city 75 per cent. of the Mahomedans were consumers, 25 per cent. of the Hindus, and 5 per cent. of the Native Christians. Mr. Lely, collector of Surat, estimated that 3,000 persons took opium out of a population of 108,000 in that city. Of these, 2,000 are Mahomedans and 1,000 Hindus; altogether about 3 per cent. of the inhabitants. Dr. Moriarty estimated the habitual consumers in Meerut at no more than 3 per cent. of the adult population. A semi-official estimate made in 1890 of the opium-consumers in the city of Bombay, showed that there were 7,000 opium-eaters in a population of 821,000, or less than 1 per cent. of the total inhabitants.

Taking India all through, it is evident that only a minority of the inhabitants, generally a small minority, even of the adult males, are opium-eaters.

The dual character of the opium habit, with its medicinal side and its euphoric side, explains some of irregularities and anomalies in its distribution. The habit prevails in excess of the average among the peasantry in low-lying, damp, and malarious districts; it also prevails in excess of the average among the

Rajputs and Sikhs, and in such cities as Lucknow and Benares, where there is a large class of idlers. In the former case the excess may be said to be due to the solicitation of the medicinal side of the habit; in the latter case the excess may be said to be due to the solicitation of the euphoric side of the habit.

Another factor which affects the distribution of the opium habit in India is the existence of groups and sects with whom abstinence from the use of opium is an article of religion. The great mass both of Hindus and Mahomedans regard opium-eating as a permissible indulgence; but certain precisians of both cults interpret their sacred writings in the sense that opium, being an exhilarant, comes under the general ban against all intoxicants, and is, therefore, forbidden to the truly orthodox. Besides these precisians who do not form separate communities there are distinct sects in which abstention from opium is an express religious obligation. Among these are the Ferazis, a sect of puritanical Mahomedans, dwelling in Eastern Bengal; these abstain not only from opium, but also from alcohol and hemp drugs. A Native witness from Assam stated that opium 'is religiously prohibited amongst the disciples of the Dehing Gossain, one of the principal spiritual guides in Assam. Any of his disciples using it is excommunicated, and never restored to society unless a severe penalty is paid.' The Buddhist priesthood in Burma appear to hold a similar attitude, and to regard the use of opium as a 'sinful vice.' In Gujarat there is a flourishing Hindu sect, numbering some 400,000 members, started about a hundred years ago, called the Swami Narayan sect, whose religious tenets include abstention from opium and all intoxicants, and even from strong smelling things such as leeks and onions.

The questions of *tolerance* and *susceptibility* are of great importance in regard to a right understanding of the opium habit, and a good deal of misapprehension has arisen from want of attention to these questions.

Tolerance.—The evidence laid before the Commission with respect to the prevalence of the practice of opium-eating, and the doses used, indicates that the natives of India have, generally, a higher tolerance for opium than Europeans—that is to say, that the former are able to bear larger doses of opium, without experiencing toxic effects, than the latter. Exceptions, of course, occur, and instances could be cited of Englishmen with as high a tolerance for opium as any recorded in India. This enhanced tolerance appears to be congenital; it is as marked in infants as in adults. In the course of his evidence on this point Dr. Crombie said: 'Most of our Ayahs, who are entrusted with the care of European children, are up-country women, who are accustomed to deal with their own children in this way (*i.e.*, giving them opium), and when they find a feverish, fretful English child, they give it the same dose of opium they would give to their own child, and the English child dies . . . we have all had experience of that kind.'

The difference of tolerance for opium between East and West was variously accounted for by the medical witnesses. Some attributed it to one cause, and some to another. It probably depends on a combination of causes—on race and climate, on hereditary acquisition by centuries of use, on the general prevalence of the malarial constitution, and the vegetable character of the diet.

But, besides this racial and climatic difference, there is a still more remarkable difference of tolerance between individual opium-eaters, depending on personal idiosyn*crasy*. Judging by the practice of opium-eaters, the average tolerance of Natives of India appears to range from 4 to 12 grains of opium per day. But many take far larger doses than these, and consume 20 to 40 grains a day, and not a few 50 to 80 grains a day, without any appreciable detriment to their health. Cases still more extraordinary were quoted before the Commission. Dr. Kailas Chunder Bose (of Calcutta) stated that he had seen a religious mendicant take in his presence about 2,000 grains of crude opium, and that the man was a perfect model of health and vigour. Another Native physician at Calcutta related that he was acquainted with a singer who, after singing for three or four hours, would take 300 grains of opium, and then would go on singing again, keeping accurately to time and tune. These figures seem to show that the range of tolerance, depending on individual idiosyncrasy, among opium-eaters is far more extended than the range of tolerance for alcohol among alcohol-drinkers, or the range of tolerance for tobacco among tobacco-smokers. Indeed, it would appear as if some men were almost insensitive to the toxic effects of opium.[1]

Susceptibility.—It has already been pointed out that opium has a dual action on the human constitution. It operates as a therapeutic agent, as an anodyne and hypnotic; and it also operates as a euphoric agent, as an exhilarant and restorative, after the manner of alcohol and tobacco. These two actions are not only not identical, but they are not always concurrent—that is to say, that persons may be sensitive to the anodyne and hypnotic effects of opium, and yet not be sensitive, or only slightly sensitive, to its exhilarant and restorative effects. The therapeutic effects of opium are much alike—tolerance apart—in all persons and in all climates, but it would seem as if only a select portion of the population were susceptible to its euphoric effects. Tobacco offers an apt illustration of this point. Tobacco-smoking is pretty generally diffused among Englishmen; yet there are a great many who never smoke, or who only smoke occasionally for company; they are abstainers, simply because they experience no enjoyment from the practice. However much they wish, and however long they try, these persons cannot become tobacco-smokers in the proper sense of the term, because they lack sensibility to the euphoric effects of tobacco.

---

[1] It is of course understood that the tolerance of a person for opium undergoes a certain, or even considerable, expansion with use. But this expansion is presumably, as in the cases of alcohol and tobacco, strictly limited for each individual according to the measure of his original endowment.

Opium, as regards its euphoric properties, seems to be even more selective than tobacco. In India, no doubt, the susceptible persons are numerous—amounting, perhaps, to a majority of the adult males in certain districts and among certain races—and amounting to a considerable number throughout the country. In Europe, on the other hand, the susceptible persons seem to be exceedingly few. Medical men are in the habit of prescribing opium every day, yet they have practically no knowledge, except from hearsay, of the wonderful reviving and exhilarating effects of the drug, of which so much was heard in India. Had there been the same susceptibility to these effects in the West as in the East, there is no obvious reason why Europeans should not have borrowed opium from India, as they had borrowed tea from China, coffee from Arabia, and tobacco from America.

Age.—The opium habit is mainly a habit of middle life and advancing years. Among young adults the habit is comparatively rare, and is only followed by persons suffering from some chronic ailment, or by idle and dissipated young men. The habit is commonly begun between 35 and 45, when life begins to be on the wane, and the premonitions of age begin to be felt. This epoch occurs much earlier with the Natives of India than with Europeans. The following table, illustrating the incidence of age on the commencement of the opium habit, has been compiled from data furnished by Dr. Hendley, at Jeypore, in Rajputana, and Dr. R. Moy Roy, at Calcutta.

TABLE I.—*Showing the Various Ages at which the Opium Habit is commenced.*

Age at which the Habit was begun	Jeypore, 4,409 cases. (Dr. Hendley)	Calcutta, 215 cases. (Dr. R. Moy Roy)
Under 20 years . .	9·39 per cent.	0·5 per cent.
20 to 29 " . . .	24·34 "	18·0 "
30 to 39 " . . .	28·06 "	47·0 "
40 to 49 " . . .	21·57 "	28·0 "
50 to 59 " . . .	11·89 "	5·5 "
60 to 69 " . . .	3·58 "	1·0 "
70 to 79 " . . .	0·82 "	0·0 "
80 to 89 " . . .	0·11 "	0·0 "

The figures in the table indicate that a larger percentage of opium-eaters begin the habit at an early age in Rajputana than in Calcutta. The general tendency of the evidence laid before the Commission on this point supports the conclusion that the Calcutta averages are more generally applicable to the whole of India than the Jeypore averages. It may be pointed out that the age-interval during which the habitual use of opium falls to its lowest point, is between the third year, when the practice of giving opium to children ceases, and the twentieth year.

Sex.—Opium-eating is much more common among men than women. Of 613 cases investigated by Dr. Vincent Richards in Orissa, 73 per cent. were males, and only 27 per cent. females. The disproportion was still greater in the 4,409 opium-eaters examined by Dr. Hendley at Jeypore; of these only 5·34 per cent. were women. This, probably, is too low an estimate for the population generally. The custom of secluding the women in India renders it difficult to get at the real facts in relation to the female sex.[1]

Dosage.—The doses taken by opium-eaters vary widely. A common allowance is from 2 to 8 grains per day—one-half taken in the morning, and the other half in the evening. Among the poor the quantity consumed is much restricted by the scanty means of the consumer. Among the easier classes the daily allowance frequently runs up to 20 and 40 grains, and sometimes far beyond this. The following tables give an excellent idea of the range of dosage among opium-eaters in India.

TABLE II.—*Showing the Range of Daily Doses used by Opium-eaters, compiled from Data supplied by Dr. Hendley, Dr. R. Moy Roy, and Dr. Huntly.*

Daily Quantity of Opium taken	Proportion of Consumers for each Range of Dosage		
	Jeypore, 4,409 cases. (Dr. Hendley)	Calcutta, 215 cases. (Dr. R. Moy Roy)	Nusseerabad, 100 cases (Dr. Huntly)
2 to 5 grains . .	21·27 per cent.	23·0 per cent.	22·0 per cent.
6 to 10 ,, . .	17·36 ,,	24·0 ,,	27·0 ,,
11 to 20 grains .	29·15 ,,	27·0 ,,	25·0 ,,
21 to 40 ,, .	18·64 ,,	16·0 ,,	17·0 ,,
41 to 90 ,, .	8·19 ,,	6·5 ,,	9·0 ,,
90 to 180 ,, .	1·47 ,,	3·0 ,,	0·0 ,,
181 to 2,000 grains	0·69 ,,	0·5 ,,	0·0 ,,

An examination of the table shows that the proportion of large consumers, in the three sets of observations, stands very high. Over 25 per cent. consumed more than 20 grains per day. Dr. Hendley and Dr. Huntly collected their cases in Rajputana, where the habit is in full development, and where opium is comparatively cheap. Dr. R. Moy Roy's cases were, for the most part, of the better classes, with whom the cost of the indulgence was of minor consequence. A very much lower scale of dosage was observed by Dr. Vincent Richards at Balasore, in Orissa. Here opium is comparatively dear, and the cases collected were mostly from among the poorer peasants. He investigated 613 cases of opium-eaters—444 men, and 169 women. The following table exhibits the range of dosage observed by him:—

---

[1] The difference between men and women in regard to the use of euphoric substances is very curious, especially as regards the more potent euphorics. In this country, probably three-fourths of the alcohol consumed is consumed by men—and the use of tobacco is almost confined to the male sex. This distinction, probably, is mainly due to a constitutional difference of tolerance and susceptibility. But

TABLE III.—*Showing the Range of Daily Dose used by Opium-eaters in the District of Balasore, compiled from Data supplied by Dr. Vincent Richards.*

Number of each Sex	Daily Quantity of Opium taken	Proportion of Consumers for each Range of Dosage, 613 Cases. (Dr. Vincent Richards)
444 men	2 to 4 grains	60 per cent.
	4 to 12 „	34 „
	12 to 16 „	4 „
	16 to 45 „	2 „
169 women . . .	2 to 4 „	79 „
	4 to 12 „	19 „
	12 to 16 „	2 „

It may be observed that the quantity used by the women was less than that used by the men. The

---

there is also a good deal in fashion. Our grandmothers and great-grandmothers used tobacco pretty freely in the guise of snuff. With the decline of snuff-taking the use of tobacco among women practically went out. But now again the fashion is changing, and the cigarette is creeping into use among women. Possibly the next generation may witness as many female cigarette-smokers in England as there were female snuff-takers a hundred years ago.

average daily dose for the men was 7 grains; the average daily dose for the women was 5 grains.

Increase of Dose and Excess.—The opium habit, once begun, is usually a life-long habit. The dose is usually taken twice a day, morning and evening, before the morning and evening meals. Sometimes the dose is taken three times a day, and sometimes only once a day, in the evening. So long as the opium-eater gets his dose punctually, and his consumption is moderate, he is quite undistinguishable from the rest of the community. His system adjusts itself perfectly to the new factor in his environment. All the functions are performed in due order, and with normal efficiency.

At the beginning of the habit there is a tendency to a progressive increase of the dose. This increase goes on until the limit of the individual tolerance is approached. When this point is reached the dose becomes stationary, and usually remains stationary for years, or for life. Sometimes an oscillation is observed, the quantity is increased for a period, or diminished for a period, according to the exigencies of health, or apparently according to the waxing or waning tolerance of the constitution.

Excess in the use of opium is to be measured not merely by the quantity habitually consumed, but much more by the constitutional tolerance of the individual. Doses which are injurious to one consumer may be quite harmless to another consumer. When an opium-eater goes beyond his tolerance, he may be said to go to excess, whether the quantity consumed be small or great. An opium-eater who, on occasion, indulges in a larger dose than his usual allowance, shows signs of opium intoxication. He becomes sluggish and drowsy; if he be a magistrate, he nods on the bench, and is, perhaps, made the subject of gentle chaff by his brother magistrates. These signs soon pass off, and leave no trace behind. But when the excess is habitual, more serious results follow. The consumer becomes persistently indolent, stupid, and incapable of attending to his business, his appetite falls off, and he becomes lean and shrivelled. The bowels are either obstinately costive, or there is alternate diarrhœa and constipation. No organic disease is developed; and the man continues to live on, provided he escape intercurrent disease, to his natural term; but his useful life is certainly shortened, and he becomes a cumberer of the ground. This is the 'opium sot,' or 'opium wreck,' of popular description, and a very deplorable object he must be. Fortunately, he is a rare spectacle, and many experienced witnesses had never seen him, and scarcely believed in his existence. It is, however, probable that the opium sot is not so scarce as his rare appearance would indicate. A man in this condition would naturally seek the shade, and keep himself out of the way.

Postponement of the Dose.—If the opium-eater does not get his dose at the appointed time he feels very uneasy; he looks stupid and exhausted, his eyes and nose begin to run; he yawns, has pains about the abdomen, and no appetite for his meal. When at length he obtains the belated dose all these symptoms vanish as if by a charm, and the equilibrium of the system is restored.

Stopping the Opium Habit.—When the supply of opium is suddenly and entirely cut off the reaction is much more pronounced than in the case of alcohol and tobacco. It is a dreaded ordeal to most consumers, and forms a serious obstacle to the giving up of the habit, when such a course is desired from motives of economy or religious scruples. It is the general rule in Indian gaols to cut off the supply of opium to prisoners on admission. The medical officers in charge of gaols were thus able to furnish the Commission with reliable and exact information on the effects of suddenly stopping the opium habit. It is true that a certain amount of smuggling of opium into gaols by friends of prisoners takes place in spite of all precautions, but that this leakage is insignificant is proved by the fact that the effects of deprivation were clearly perceived by the medical officers of the prisons, and that their testimony as regards these effects was remarkably uniform. The usual effects of stoppage are:—looseness of the bowels, dejection and misery, restlessness and loss of sleep, failure of appetite, aching of the bones, lassitude, and weakness. These symptoms are more or less severe and protracted according to the largeness of the dose to which the prisoner has been accustomed and the length of time during which the habit has been continued. A good deal also depends on the temperament of the sufferer. A man of nervous quasi-hysterical temperament suffers more than a man of more stolid disposition. After a few days, or a week or two, these symptoms subside and health is restored. As a rule the disturbance is slight and calls for no interference in the way of special treatment on the part of the medical officer. Sometimes, however, the disturbance is more severe, and may even, in exceptional cases, assume alarming proportions. In these latter the initial shock approaches to a state of collapse, or the looseness of the bowels passes on to intractable diarrhœa of dysenteric character. In such cases the medical officer is obliged to resort to the use of opium again, and to finally withdraw it by slow degrees. Instances are not unknown, though seemingly of extreme rarity, where life has fallen a sacrifice to the process of stopping the opium habit. Such instances are, however, only known in the case of prisoners whose health is seriously deteriorated by the excessive use of the drug, or who are at the time suffering from some intercurrent disease.

The Opium Habit and Food.—The Commission were frequently told that people who were well off and had plenty of good food tolerated the opium habit with impunity, whereas the poor, with an insufficient supply of food, suffered from it. On the other hand, we were often told that opium ameliorated the lot of the under-fed man, and enabled him to live longer and better with a scanty diet. This latter view seems to be largely held by medical men in India; and it is interesting to note that physiologists in Europe have held a similar opinion with regard to alcoholic beverages and tea and coffee—namely, that one of their purposes to the poor consumer was to serve as economisers of food. There may be an element of truth in both these allegations. A large consumer might spend too much of his scanty income on opium, and leave too little for food, and thereby aggravate his condition; while a frugal consumer might benefit from spending a small modicum of his earnings on opium, and thereby making his scanty meals go farther.

Opium is said to be useful to those who live chiefly on rice. Dr. Cobb explained this point in the following way: 'In the damp climates of Eastern Bengal the poor Natives are in the habit of eating largely of rice, and a peculiar sensitiveness of the bowels seems to exist in those damp climates. As a man advances in age digestion fails to some extent, and the food is hurried through the intestines. . . . The effect of hurrying food through the intestines is to cause diarrhœa, dysentery, and other allied affections. Opium in small doses prevents this, and it is largely used by the poor in Eastern Bengal.

Dr. Elizabeth Bielby, examined at Lahore, stated that it was a general practice in the Punjab for the women to take a small dose of opium (about a grain) just before or with their midday and evening meals, as a 'digestive.'

But the most curious relation of opium to food is the practice common to opium-eaters of indulging largely in milk, ghee (clarified butter), and sweetmeats. This kind of food is believed to help the opium to agree, and also to prevent or postpone the injurious effects of the immoderate use of opium. And it was constantly alleged that the poor, who cannot afford these indulgences, suffered in consequence more from the abuse of opium than well-to-do people. There are probably sound reasons for this practice. One of the plagues of the opium-eater is chronic constipation, and free use of milk, ghee, and sweetmeats would help to keep this tendency in check. Another tendency of opium-consumers is to grow unduly lean, and a good many confirmed and large opium-eaters are noted as spare, wiry men. Milk, ghee, and sweetmeats are eminently fattening articles of food, and very easily digested; these articles would therefore be a peculiarly fitting addition to the dietary of an opium-eater.[1]

Effect of the Opium Habit on Health and Longevity.—It is a matter of no small difficulty to justly assess the influence of the opium habit on the health and longevity of the consumers. On the one hand, a large body of evidence was laid before the Commission to the effect that opium-eaters were, to an important extent, protected by the habit against the inroads of diarrhœa, dysentery, ague, and other maladies incidental to damp and malarious climates, and that lives innumerable were thus saved. On the other hand, valid evidence was adduced that the habit tended to habitual excess, and that excess was injurious to health, and that many lives were lost in consequence. Both these contentions may be taken as true; and the problem is to balance the gains and losses. It is obvious that such a problem is, from its very nature, incapable of an exact numerical solution; and the inquirer is constrained to draw his conclusions from an examination of a number of separate items of evidence and a broad consideration of the general tendency of that evidence. Proceeding in this way, and judging from the aggregate of the evidence laid before the Commission, it does not seem possible to doubt that the lives saved by the opium habit, as practised in India, and under the climatic and other conditions prevailing in India, outnumber the lives lost through the habit. A good deal of the evidence on which this conclusion is based will be disclosed subsequently in dealing with the subject of opium as a household remedy and as a prophylactic against malaria. The following points may be dealt with here:—

---

[1] Dr. Polak relates that at the age of 40 every Persian who wants to avoid obesity takes daily an opium pill. (Cited by Dr. Ernest Martin, *L'Opium*, p. 18.)

The opium habit does not appear responsible for *any disease peculiar to itself*; and post-mortem examinations of opium-eaters who had died of natural disease have not revealed any tissue changes, or disease of any organs, which could be traced to the use or abuse of opium. Neither does the habit affect the chances of life after surgical operations. Opium-eaters *bear operations* as well, and recover from them as quickly, as those who are not addicted to the habit. The testimony of hospital surgeons in India on both these points was practically unanimous.

The general health of opium-eaters, provided they keep within their tolerance, appears to be just as good as that of other people. A considerable number of confirmed opium-eaters appeared before the Commission as witnesses; and they could not be distinguished in any way from other persons of the same age and station in life.[1] Numerous instances were mentioned, both by British and Native witnesses, of persons who had reached an advanced age, although they had habitually consumed large quantities of opium for 20, 30, and 40 years. Remarkable evidence on this point is supplied by the table of 215 opium-eaters examined personally by Dr. Moy Roy at Calcutta. Of these 215 persons, fifty-two were between 60 and 70 years of age, eighteen between 70 and 80, and five between 80 and 90 years of age, and one died at the patriarchal age of 106 years, after having consumed the enormous dose of 180 grains of opium daily for 66 years. Out of these 215 persons, 213 were still living at the date of the record, and of the health of these Dr. Moy Roy remarks: 'With the exception of seven persons, who are in indifferent health, all these persons may be said to be in good condition of body and mind, of course making allowance for the age of those who are old. The rest of the number were found to enjoy good health of body and mind, equal in every respect to that of the average Native not given to this habit.'

---

[1] By the courtesy of Surgeon-Captain Jennings, 20 Native soldiers of the 32nd Pioneers were paraded before me at Umballa. Of these 10 were opium-eaters and 10 were not. I examined them carefully, and tried to pick out the opium-eaters. I entirely failed; sometimes I was right and sometimes wrong, and as often wrong as right. The opium-eaters were not large consumers; their daily doses varied from 4 to 8 grains.

Some of the medical witnesses expressed the opinion that opium-eaters, especially those who consumed immoderately, had a less chance of recovery from *intercurrent disease* than those not addicted to the habit. Dr. Mullane put the matter in this way: 'For although opium-eaters do undoubtedly enjoy a marked degree of immunity from malarial fever, dysentery, or diarrhœa, still an old opium-eater attacked with dysentery or diarrhœa enjoys a smaller chance of recovery than a non-opium eater.' It seems highly probable that persons who have habitually gone to excess in the use of opium would thereby lower their vitality, and thus diminish their power of resisting the attacks of intercurrent disease.

The habitual use of opium does not appear to affect *longevity*. The late Sir Robert Christison, in 1845, published biographies of 25 opium-eaters collected by himself. He came to the conclusion that the evidence thus collected rather tended to throw doubt over the popular opinion that the opium habit shortened life ('Treatise on Poisons,' p. 718). Mr. McLauchlan Slater, manager and actuary of a large insurance company at Bombay, engaged in the business of insuring Native lives, had come to the conclusion, after 20 years' experience, that it was not necessary to put an extra premium on the lives of moderate opium-eaters.

Insanity.—The evidence tendered by the medical officers in charge of lunatic asylums in India was uniform to the effect that the opium habit is rarely if ever a cause of insanity. Dr. Crombie analysed the statistics relating to the causes of insanity in the asylums of Lower Bengal, the Bombay Presidency, and the Madras

Presidency. In Bengal the proportion of opium-eaters among lunatics was 0·36 per cent.; in the Bombay Presidency 0·75 per cent.; and in the Madras Presidency (only one year's returns available) no opium-eaters figured among the admissions. He remarks that 'it would become almost justifiable to advance the theory that one of the advantages derived from the habit of eating opium is a diminished liability to insanity.'

Dr. Boyd, superintendent of the Colaba Lunatic Asylum, Bombay, containing an average number of 285 inmates, stated that in 11 years only three cases were admitted in which opium was put down as the probable cause of the insanity. He further says, 'I do not think that opium has ever produced or ever will produce insanity; that is my very strong opinion. It may, in large doses, produce hallucination for a short time, but never insanity of any form.'

Suicide.—Some of the witnesses expressed the opinion that the opium habit in India was promotive of suicide. One witness contended that opium 'is of all poisons the one which must be most attractive to a suicide. It presents death in its easiest and most delightful form to one who has reached that state of mind. I believe that its free sale does greatly encourage suicide.' This plausible view is, however, not supported by an examination of the official statistics of suicide in the different provinces of India. The following table (Table IV.) shows conclusively that the prevalence of the opium habit has no relation to the frequency of suicide:—

Table IV.—*Showing the Proportion of Suicides by Opium to the Total Suicides in the several Provinces of British India; compiled from the Official Statistics printed in Vol. v., Appendix xvi., of the Report of the Opium Commission.*

Provinces	Total Annual Suicides per Million of Population	Proportion of Suicides by Opium to Total Suicides	Annual Average Consumption of Opium per Head of Population
North-West Provinces and Oudh:			
Average of 5 years . .	61	13·5 per cent.	24 grains[1]
Madras Presidency:			
Average of 5 years . .	54	0·05 ,,	14 ,,
Central Provinces:			
Average of 5 years . .	49	2·4 ,,	34 ,,
Bombay Presidency and Sind:			
Average of 4 years . .	46	9·5 ,,	46 ,,
Bengal:			
Average of 5 years . .	39	11·1 ,,	15 ,,
Punjab:			
Average of 5 years . .	24	9·0 ,,	42 ,,
Assam:			
Average of 3 years . .	20	5·0 ,,	141 ,,

It will be observed from an examination of Table IV. that, taking all the provinces into consideration, the percentage of suicides by opium has no relation to the general prevalence of suicide. For although the figures for the North-Western Provinces appear to show the existence of such a relation, inasmuch as the proportion of suicides per million of the population and the percentage of these due to opium both stand highest on the list, the figures for Madras and the other provinces entirely negative this deduction. Nor is there any connection between the amount of opium consumed in a province and the prevalence of suicide in that province. The province of Assam, which has the largest consumption of opium, shows the smallest proportion of suicides; and Madras, which has the lowest consumption of opium, stands second on the list in proportion of suicides.

---

[1] This is the consumption for the North-West Provinces; the annual consumption for Oudh is 15 grains per head.

Relation of the Opium Habit to the Generative Functions.—Opium has a repute as an aphrodisiac all over the East. But as it shares this repute with a score of other drugs and nostrums the fact loses much of its significance. Aphrodisiac agents have lost credit in modern medicine, and it is very doubtful if opium have any special power in this direction. The medical witnesses were by no means in agreement on this point. Some said opium stimulated the sexual function; others said it was not so, but that it protracted the orgasm; others, again, said it was at first provocative and that afterwards it produced impotence. The truth probably is, that the general stimulating and restorative effects of opium on the Natives of the East, like those of alcohol on the Natives of the West, extend to the sexual function, but that they have no special relation to that function. It is also probable, and more than probable, that the deadening of the vital functions which overtakes the opium-eater who habitually exceeds his tolerance, involves the sexual function, and tends to impotence.

Attention was called by Dr. Vincent Richards to the diminished fecundity of opium-eaters. Speaking from a careful study of 613 opium-eaters in Orissa, he says: 'There is one almost inevitable result of a prolonged indulgence in opium-eating, especially if immoderate—namely, a weakening of the procreative powers. In no fewer than 99 cases out of 125, into which I particularly inquired with a view to ascertaining the fact, was this the case; moreover, of the 125 married men averaging 36 years of age, the average number of children to each was 1·11, after 11 years of married life. The average dose taken by these men was 14 grains *per diem*, and the length of time they had been addicted to the habit, 12 years.' The statistics collected by Dr. Hendley at Jeypore seem to point in the same direction, but not nearly so strongly. He made inquiries as to the number of children of 4,389 opium-eaters; of these, 2,798 had issue—namely, an average of 2·9 children to each person; while 1,591 had no issue—so that for the whole number there was only an average of 1·8 child for each person.

I scarcely know how to interpret these figures. There is certainly no lack of fecundity in India. The population shows a satisfactory normal increase in every province, and the birth-rate throughout the country is higher than in England. The birth-rate in England averages 31·4 per 1,000, while in India the birth-rate averages over 42 per 1,000. It must be remembered that the opium habit is in the main a habit of middle life and advancing years, and is not often practised in youth and early manhood. On the other hand, the congress of the sexes takes place very early in India, and chiefly before the opium habit has attained much development. Perhaps the explanation of the apparent paradox lies in these two circumstances.

(2.) OPIUM AS A HOUSEHOLD REMEDY IN INDIA.

Opium is largely employed all over India as a domestic medicine, and centuries of use have familiarised the inhabitants with its administration, both as an internal remedy and as an outward application. It is resorted to in the manifold ailments incidental to damp and malarious climates—in diarrhœa, dysentery, chills, recurrent febrile attacks, and the neuralgic troubles of the malarial cachexia. It is also their chief resource in asthma, chronic coughs, rheumatic pains, diabetes, gravel, and indeed in all painful wasting diseases of every kind.

It is a fact which was brought to the knowledge of the Commission during their tour in India that large masses of the people are as yet beyond the reach of European medical aid. The dispensary system which has been organised throughout India is still inadequate for the immense needs of the population. The Native practitioners—the Hakims and Vaids who follow the Arabic and Hindu systems of medicine—are without any regular training; they are self-taught and self-appointed, and the knowledge of medical matters possessed by many of them is not much greater than that of the people among whom they practise. The consequence is that the medical aid available for the sick, especially among the poor, is often solely that of the house-wife, or of the wise woman of the village.

Dr. Maynard informed the Commission that the district of Nuddea, in Bengal, where he had been stationed as civil surgeon, possessed an area of 3,404 square miles, with a population of over 2,000,000. He was the only European medical officer in that district. He had to aid him an assistant-surgeon, with a number of Native unqualified hospital assistants, and five dispensaries scattered over the district. But there were large numbers of people who could not avail themselves of these dispensaries, and who could not travel the necessary distance. The last report of the medical institutions of Bengal shows that in a population of over 70,000,000 only a comparatively small percentage got any benefit from the Government medical institutions.

It is not difficult to understand how, under these circumstances, opium, with its unrivalled power of alleviating pain and producing sleep, and of controlling the intestinal fluxes which the Natives so justly dread, should have become an indispensable article in Indian households.

The testimony of some of the most experienced members of the Indian Medical Staff in regard to the value of opium as a domestic remedy was impressive. Surgeon-Major-General Rice, speaking from an experience of 37 years, said: 'In the Central Provinces malarial fevers, with severe ague, and dysentery, and diarrhœa, and, I should add, rheumatism, are diseases with which the people are afflicted. In these, muscular pains, nervous irritability, griping, and tenesmus are common and persistent, symptoms causing an amount of depression and inability to exert oneself that can only be appreciated through actual suffering. . . . It may, I think, be safely stated that not 10 per cent. of the population all over India ever consult a medical man of any nationality practising the European system of medicine. . . . Practically, therefore, the great majority of the population are beyond the reach of such advice. The consequence is that either they must consult Hakims or Vaids, who invariably administer opium for these torments, or they have discovered its beneficial effects and take it themselves. They soon have to take it regularly, for these torments are ever present in one form or another, and seriously hinder the people in their work. The effect in such cases is magical; a man literally disabled from these ills, after a dose of a quarter or half a grain of pure opium, in a few minutes becomes a new man, and is able to do a full day's work. He knows that if he cannot do this he and his family must starve.'

Surgeon-Lieut.-Colonel Crombie, now Superintendent of the General Hospital in Calcutta, was equally emphatic. He stated in the course of his evidence: 'I think it is desirable that the Commission should know something of the conditions of life obtaining in a place such as I have lived in for a great part of my service in India; I refer to Eastern Bengal. There, when a man wants to build a house, he first of all digs a tank, and with the earth from which he has dug the tank he raises a mound, and on the top of that mound he places his house. The elevation of that mound depends entirely upon the height to which the annual floods rise. The floods rise with fair regularity; but sometimes they go two or three inches higher than the average, and then the inhabitants of those houses have to live on rafts inside their houses and their cattle are tethered up to their bellies in water. These people have generally no boats. They paddle about on rafts made of the plaintain tree, and the boys go to school in what I call washhand basins. They are earthern gumlas. The boy squats at the bottom of the gumla and paddles to school. This is the only means of communication. Some of those dwellings are extremely isolated. There may be only one household within four or five miles. There is no Native doctor or dispensary within five or ten miles of them. I am convinced that to deprive these people of the possession of opium, except under medical advice, would be a terrible and wanton cruelty. It is the only medicine of any value that is available to them, and if you deprive them of it I should not like to be one of those who do it.'

(3.) Opium as a Remedy and Prophylactic against Malaria.

The belief in the usefulness of opium in the complaints of damp and malarious regions is very widely spread. It is well known that there used to be a disproportionately large consumption of opium in the marshy districts of England—in the fens of Cambridgeshire and Lincolnshire, and in the Romney marshes. These parts were formerly highly malarious, and laudanum was enormously used as a household remedy.[1] As the marshy lands were drained, and ague diminished, and as also quinine became better known and cheaper, the consumption fell off, but it is still said that there is more laudanum sold in those districts than in any other parts of rural England. The same belief seems to have prevailed long ago in Persia. Shah Abbas II., in 1621, issued an edict prohibiting the use of opium in his dominions, on account of the abuse of the drug which had crept into the army, but he exempted from the prohibition the populations which were exposed to the miasmata of marshy regions.[2] Dr. Polak states that opium is used in large quantities on the swampy shores of the Caspian Sea, as a protective against malaria.[3] The evidence laid before the Commission showed that in some districts of India the local consumption of opium bore a close relation to the greater or less prevalence of malaria in the localities.[4]

---

[1] Some interesting evidence on this point is recorded in the Proceedings of the Commission (Vol. IV., p. 16).

[2] Cited by Dr. Ernest Martin (*L'Opium*, p. 16).

[3] Cited by Dr. Ernest Martin (*L'Opium*, p. 18).

[4] A striking illustration of this was given by Mr. Wace, Commissioner of the Patna Division. He stated: 'The effect of climate in regulating the use of opium is curiously illustrated in the district I know best, viz., Bhagalpur. The district is cut in halves by the Ganges. The southern part is dry and healthy; the eastern half of the northern part is damp and malarious, especially where it borders the River Kosi. The three most malarious thanas, Kishengang, Madhepura, and Partagang, with a population of 27 per cent. of the whole district, have 42 per cent. of the opium shops licensed for the whole district. The three driest thanas of the south, containing a population about four-fifths of the damper thanas, have only two opium shops, while the three damp thanas have seventeen.'

India is more or less malarious from end to end, and suffers severely from the diseases incidental to such climates. A glance at the official statistics of the causes of death in British India shows that 'fevers,' by which are meant malarial fevers, overshadow all other causes of mortality. In the provinces of Bengal, Bombay, Punjab, and the North-Western Provinces these fevers account for about 70 per cent. of the total deaths; in the Central Provinces, for about 60 per cent.; in Assam, for about 50 per cent.; in Berar, for about 45 per cent.; and in Madras, for about 38 per cent. of the total deaths. These numbers are probably, as I have gathered from conversations with medical officers in India, somewhat excessive. Pneumonia and other acute diseases are sometimes erroneously included under the heading 'fevers,' but making allowance for all errors of diagnosis, the main fact remains, that malarial fevers dominate the death-rate in every province of British India. The next most prolific causes of mortality are dysentery, endemic diarrhœa, and cholera. These, roughly speaking, account for about 12 per cent. of the total deaths. Such being the dominant conditions of morbidity, it is easy to understand how opium has come to be regarded by the Natives of India as a general panacea for their health troubles. The people have learnt from long experience that opium is to them a help in need, both to alleviate their sufferings, and, more or less, to prevent a recurrence of their feverish attacks. In this general sense there was a consensus of opinion that opium was an invaluable mitigator of, and prophylactic against, the prevailing complaints of the people of India; nor was there any doubt expressed that, as regards its general therapeutic value, opium could not be replaced by any other known remedy.

A more interesting question from a scientific point of view is, whether and to what extent opium has the power to cure and prevent genuine malarial fevers; in other words, whether opium possesses, like quinine, real antiperiodic properties. In order to elucidate this point, it is necessary to advert to the composition of opium and, particularly, of Indian opium. Opium is a very complex substance, containing not less than 16 or 18 different active principles; most of these are in very minute proportions, and do not concern us here. The two most important and abundant alkaloids, or active principles, of opium, are morphia and anarcotine.[1] Morphia represents the anodyne and hypnotic properties of the drug. Anarcotine is a bitter crystalline alkaloid resembling quinine, and, like that substance, possesses tonic and antiperiodic properties.

There are two descriptions of opium current in India—namely, Patna opium and Malwa opium. The opium used in England for medical purposes is called Smyrna opium. There are considerable differences in the proportions of morphia and anarcotine in these three varieties. These differences are shown in the subjoined Table:—

TABLE V.—*Showing the Percentage of Morphia and Anarcotine in Patna, Malwa, and Smyrna Opium; compiled from the Patna Opium Factory Laboratory Records (Report of the Opium Commission, Vol. ii., Appendix xx.)*

Description of Opium	Morphia	Anarcotine
Patna opium (Behar provision cake)	3·98 per cent.	6·36 per cent.
Malwa opium	4·61 "	5·14 "
Smyrna opium	8·27 "	1·94 "

It will be observed that Patna opium is comparatively poor in morphia, but very rich in anarcotine. Smyrna opium, on the contrary, is very rich in morphia, and very poor in anarcotine. Malwa opium is closely akin to Patna opium, but is a little richer in morphia, and a little poorer in anarcotine. Persian opium, of which a good deal finds its way into some parts of the East, appears to be almost identical with the Malwa variety in its percentage of morphia and anarcotine.

---

[1] This substance was named Narcotine by its discoverer, Derosne, but this designation is so misleading (seeing that it is devoid of narcotic qualities) that Dr. Palmer re-named it Anarcotine. Dr. Garden adopts this name, and I think it desirable to follow his example.

Some 50 years ago quinine became very scarce and dear, and the Indian medical authorities had to cast about for some cheap and more abundant substitute. Attention was directed to anarcotine, and trials were made as to its curative power in malarial fevers. In 1838 Dr. (afterwards Sir William) O'Shaughnessy, of the Indian Medical Service, brought before the Medical Society of Calcutta an account of 32 cases of intermittent and remittent fevers treated with anarcotine. Of these 31 were cured. He also mentioned that 100 cases were treated by his pupils and acquaintances with perfect success. These results and others of a like character caused the Indian authorities to institute further experiments, and, these proving favourable, they caused anarcotine to be prepared in quantity at the laboratories of Ghazipur and Patna and distributed to the medical depôts throughout British India.

Two important communications on the antiperiodic powers of anarcotine deserve resuscitation. They are based on a large experience, and they prove incontestably that anarcotine is scarcely inferior—and, in some classes of cases, is superior—to quinine as an antiperiodic. The first, from Dr. Palmer, is contained in a letter to the Director General of the Indian Medical Department, and is printed in Vol. V. of the Proceedings of the Opium Commission, Appendix III., p. 78. In 1857–9 he treated at Ghazipur 546 cases of malarial fever with anarcotine, in doses ranging from 1 to 3 grains. Of these 541 were cured and five died. In addition to these 546 officially reported cases, he treated with anarcotine a large number of other cases of malarial fever, amounting in all to little short of 1,000 cases. Summing up his general experience, he states that in 70 per cent. the fever was permanently arrested at the second paroxysm after the medicine was administered; in 20 per cent. the arrest was equally sure, but was not quite so quick; and in 10 per cent. the medicine did not appear to have any curative result. He further remarks that there are cases where anarcotine is decidedly more efficacious than quinine—namely, where there is an intolerance of quinine, and where quinine has been given without any effect for a long time.

The second communication is a 'Report on Anarcotine,' by Dr. Garden, which is published in the 7th volume of the 'Indian Annals of Medical Science.' Dr. Garden succeeded Dr. Palmer in civil charge of the Ghazipur station in 1859; and at that time a severe outbreak of intermittent fever, of quotidian and tertian type, had to be dealt with. Taking advantage of the opportunity, he subjected anarcotine to an extensive trial. He treated altogether 684 cases, and gives details of 194. Of these 194 cases, 187 were rapidly cured by anarcotine. It only failed in seven cases, or 3·6 per cent. It, moreover, cured some cases where quinine had failed. The doses he employed ranged from 1½ to 3 grains. He expresses his general conclusions in the following words:—'That it (anarcotine) is of equal value to quinine I do not pretend to say, but that it has a claim to the next place in the ranks of antiperiodics is, I think, an undoubted fact.'

Anarcotine continued in large demand, and was regularly supplied from the Government factories until some 15 or 20 years ago, when, quinine becoming again cheap and abundant, the Medical Department refused to issue anarcotine to the medical depôts, and the factories ceased making it.

The bearing of the observations of Dr. Palmer and Dr. Garden on the prophylactic powers of opium against malarial fevers stands as follows. These observers found that anarcotine in doses of 1 to 3 grains rapidly (in about three days) cut short the paroxysm of intermittent fever and completely arrested the disease. Now Patna opium is estimated to contain 6·36 per cent. of anarcotine. It would, therefore, require 16 grains of crude opium to equivalise the minimum dose of 1 grain of anarcotine, which was found effective in arresting the paroxysms of intermittent fever, and 48 grains to equivalise the maximum dose. From these calculations it may be inferred that only large consumers of opium would be absolutely protected against the malarial poison. A reference to Table II. shows that in Calcutta and Rajputana some 30 to 40 per cent. of opium-eaters might be thus protected, but in Orissa, where the dosage is smaller (Table III.), only some 4 per cent. would be completely protected. It is, however, to be remembered, that a dose of an antiperiodic, which is insufficient to cut short an actually existing attack of intermittent fever, may be sufficient to ward off an attack—that is to say, may be sufficient to act as a prophylactic. This is at least the case with quinine. During an attack of ague, quinine is given in doses of five to ten grains—but a dose of two grains taken daily is held to be effective as a prophylactic against recurrent attacks. The same rule probably holds good as regards opium, and its alkaloid anarcotine. On this view it may be assumed that moderate consumers of opium, although not rendered absolutely immune against the malarial poison, would be more or less protected from recurrent attacks--and if the attacks returned, they would return less frequently and with mitigated severity. These particulars, I think, adequately explain why opium-eaters are not altogether exempt from malarial fevers. The smaller consumers either lack the means, or they lack the tolerance, which would enable them to take opium in sufficient quantity to contain an efficient protective dose of anarcotine.

The question was often mooted before the Commission, why it was that, notwithstanding all this evidence in favour of opium in malaria, medical men in India did not prescribe opium for the cure and prevention of malarial fevers. The explanation is very simple in the light of the facts disclosed above. Opium contains morphia as well as anarcotine. This puts an absolute bar to the use of opium as a general antiperiodic. It could not be so used without the most serious risk of narcotic poisoning. Only persons of proved high tolerance for opium, in other words, seasoned opium-eaters, could with safety take a sufficiently large dose of the drug to bring into efficient play the antiperiodic power of the anarcotine contained in it. This is the reason why crude opium can never take the place of quinine as an antiperiodic medicine—not even in the case of the generality of the Natives of India—still less in the case of European residents in India.

It seems highly probable that some of the other ingredients contained in opium, and especially morphia, are of service to the sufferer from malaria. In the condition termed 'malarial cachexia' the poison lingers about the system for months and years—but not in sufficient potency to keep up regular febrile paroxysms.

Such persons are liable on slight exposure or chill to have a recurrence of the paroxysms; they are then said to be 'down with fever.' This state of things is well known in India. The opinion was very generally expressed by the medical witnesses, that in the case of Natives thus affected the habitual use of even a small dose of opium, or an occasional dose when the emergency arose, served to ward off the provocative chill and thus prevented these relapses.

It was also alleged that opium often acted as an indirect prophylactic against malaria, by checking diarrhœa and dysenteric purging. These complaints greatly reduce the strength of the sufferers, and so render them more susceptible to the malarial poison and to the 'chills' which are universally recognised in India as the immediate cause of fresh attacks of fever.

Several medical witnesses deposed that they had often found opium in combination with quinine to act better as an antiperiodic than quinine alone.

Plurality of Malarial Infection.—Dr. Crombie called attention at Calcutta to a matter of great interest concerning the pathology and therapeutics of malarial fevers—namely, the existence of more than one kind of malarial infection. He said: 'When one comes to India the first thing that strikes one is what seems to be the rooted and unreasonable objection that the Natives sometimes have to be treated with quinine. . . . After a time one finds out that this objection is not unreasonable, and that there are a great many fevers—I might almost say the majority of cases of fever which I have to treat in Bengal—which are not only not benefited by quinine, but which are aggravated by it.' Surgeon Lieut.-Colonel O'Brien said: 'Latterly my experience has been enlarged in the treatment of fevers, and I have come to recognise . . . the disadvantage of quinine in many cases, and the undoubted remarkable benefit to be derived from the use of opium.' Surgeon Captain Tull Walsh, speaking from his experience in Orissa, stated that in that province the fevers accompanied by enlarged spleens were not so common as the type of fever not so accompanied—and that he believed that these two distinct diseases had got muddled up under the head of 'malaria.'[1]

The recent researches of Laveran in France, of Marchiafava and Bignami in Italy, and of Mannaberg in Germany, come opportunely to Indian inquirers as bearing on the question of the existence of a plurality of type and plurality of infection in malarial fevers. These researches have demonstrated that the infective material of malarial fevers consists of micro-organisms living and multiplying in the bodies of the affected persons, and that these micro-organisms are of more than one kind, and give rise to more than one type of fever. Clinical inquirers in India have in this connection some extremely interesting pathological and therapeutical questions ripe for investigation—and it is not improbable that Indian opium, or rather its chief alkaloid anarcotine, may come to play a larger part in the treatment of Indian fevers in the future than in the past—and that anarcotine may eventually take its place, not as a rival to quinine but side by side with it, as a twin antidote to malarial poisons, each being superior on its own special ground.

The facts above enumerated go far to account for the diversity of the testimony laid before the Commission on the relations of the opium habit to malaria. It has been shown how small consumers of opium would be less effectively protected than large consumers, and how even large consumers would not be rendered immune against every form of malarial fever. The fact, now established, that malarial fevers are not all of one type throws a new and important light on the subject. The type of malaria prevailing in one district might be amenable to the control of opium, while a different type prevailing in another district might not be thus amenable —and, naturally, the popular belief in the two districts as to the protective or prophylactic power of opium against malaria would vary accordingly.[1]

---

[1] It is interesting to note that 35 years ago Dr. Palmer surmised the existence of a plurality of malarial poisons. In the communication before referred to he states that in 90 per cent. of the cases of malarial fever treated by him at Ghazipur anarcotine effected a rapid cure, but that in 10 per cent. it proved entirely ineffective. 'This class,' he says, 'contrasts so strongly with the former that I have been constantly led to believe there must be some difference in the character of the fever.'

It may also be remarked that the non-medical witnesses had not always sufficient knowledge to enable them to distinguish between malarial and non-malarial fevers. Thus some of the witnesses from Assam based their disbelief in opium as a remedy and prophylactic against malarial fever on its inefficacy in an epidemic disease called Kala-azar, which a few years ago caused great ravages in that province. It turns out that Kala-azar is not a malarial fever at all—but a contagious fever of quite a different nature, which is not influenced by any antiperiodic remedy. (See an elaborate official report by Dr. Giles on Kala-azar and Beri-beri printed at Shillong, in Assam, in 1890.)

---

[1] Parasitic diseases are, as is well known, greatly influenced as regards their incidence by racial distinctions—and this peculiarity appears to apply to some types of malarial fever. In India the common types of malarial fever attack Natives and Europeans impartially; but this does not appear to be the case with all types of malarial fever. I have been informed that there are hill tracts in India which prove highly malarious to the European officials stationed in them, but which are *not* malarious to the Native inhabitants.

(4.) THE PRACTICE OF GIVING OPIUM TO INFANTS.

One of the most singular outgrowths of the opium habit in India is the custom of administering opium to infants. The practice is an ancient one and prevails extensively all over India, but especially in the North-Western provinces, in the Native States of Rajputana and Malwa, and in the Bombay Presidency. The practice may be considered as part and parcel of the household, or popular, use of opium. The Commission were repeatedly told that 60, 80, and 90 per cent. of the infants were dosed with opium, and with some castes the custom seems to be universal. The practice is begun in the first few weeks or months of life, sometimes even from birth, and is continued up to the end of the second or third year, and sometimes to the fourth, and very rarely to the fifth year. The dose is usually one-sixteenth to one-twelfth of a grain to begin with, and this is gradually increased to a quarter or half a grain, and even to one or two grains, according to the age and necessities of the child. The dose is generally administered night and morning, sometimes only once a day. In most parts of India it is given by the mother in the form of crude opium, a speck about the size of a poppy seed or pin's head is put into the child's mouth or is mixed with its milk. Sometimes suckling mothers smear their nipples with opium. In Bombay 'children's pills,' or 'bala-golis,' are extensively sold for this purpose. These pills are now manufactured, in order to ensure purity and constancy of strength, under the supervision of the licensed vendor; they are made of two degrees of strength and contain respectively one-sixth and one-third of a grain of opium each, mixed with a variety of harmless spices.[1]

---

[1] The exact quantity of opium in each pill, of the two degrees of

When the child reaches the age of two or three years the practice is discontinued. The weaning from opium is usually done gradually; but it is quite complete; and any resumption of the habit in adult life is entirely disconnected from the practice in childhood.

The common purpose for which opium is given to infants by the poor and cultivating classes is to keep the children quiet and free from fret while the mothers go about their work in the house or in the field. Dr. Keegan, at Indore, gave us the following touching glimpse of the practice:—'A peasant woman who has to work in the fields gives her child some opium and puts him in a basket in the corner of the hut, or perhaps she takes her child with her to the field, puts him in a small basket, and gives a little opium to keep him quiet.' But this custom is by no means confined to the poor and the peasantry, who cannot afford to provide the mother with additional help in the charge of her children. It is followed pretty generally among the well-to-do classes, and even in the zenanas of the rich, where there is no lack of servants to attend to the duties of the nursery. The reasons given for the practice by the Native witnesses were, that the opium not only kept the children quiet and comfortable, but also helped them to digest their milk; that it prevented diarrhœa, warded off chills and fever, served to alleviate the troubles of dentition, and generally helped to keep the children in good health.

The advantages and disadvantages of this custom were a good deal canvassed before the Commission. It was shown that accidental poisoning sometimes attended

---

strength, is nine-fiftieths and nine-twenty-fifths of a grain. It is to be remembered that Indian opium contains only half the amount of morphia contained in the opium used in Europe for medical purposes.

the practice. Children were occasionally brought to the dispensaries in a state of somnolence or coma, from accidental over-dosing by a mother, or from a child getting hold of a lump of opium or a box of bala-goli pills left carelessly about, and so poisoning itself. Most of these cases issued in recovery, but sometimes fatalities occurred. These accidents were not nearly so common as might have been expected—showing the practised skill of Indian mothers and nurses in the management of the drug. Some of the medical witnesses expressed a doubt whether fatalities from this cause were more frequent in India than occurred at home from opium given to children in the form of soothing syrups and cordials, or dispensed under medical prescription. Dr. Blaney, who was coroner of Bombay for seventeen years, could only recall five or six fatal cases of infants being accidentally poisoned in this way.

As regards the general question of the usefulness or hurtfulness of the custom, viewed apart from the risks of accidental poisoning, the opinions laid before the Commission were divided.[1] To European ideas the practice seems very objectionable. The surroundings of child-life in India are, however, so peculiar, in relation to domestic circumstances, to food, climate, and malarial influences, and as regards the exceptional tolerance for opium of Indian infants, that it would not be safe to judge the custom by European standards.

Indian mothers and nurses, and the Native public generally, have an unquestioning faith in the wholesomeness of giving opium to children, and the accumulated experience of successive generations of parents, extending over hundreds of years, furnishes a body of presumptive evidence which is not to be lightly set aside on the ground of *à priori* considerations. It is difficult to believe that a practice so widely diffused through all grades of society, and carried on under the direct supervision of the vigilant maternal instinct, should have maintained itself so long in credit, if it were on the whole and to any appreciable extent injurious.

---

[1] In a memorandum on children's pills or bala-golis, presented to the Commission by Mr. McNabb Campbell, collector, of Bombay, it is stated :—'Bombay professional opinion is almost equally divided on the question whether opium is beneficial or hurtful to children. Of 84 statements obtained in 1893 from members of the Grant College Medical Society, 27 were in favour of the use of the drug, 30 were against it, 25 gave no opinion, and two were doubtful.'

The general tenor of the evidence of the members of the Indian Medical Service, who had charge of dispensaries and had supervision of vaccination, and had thus ample opportunities of observing the effect of the habit, was to the effect that the practice was generally harmless and sometimes beneficial. It was shown that the children who had opium given them were just as healthy as those who had not opium given them. Dr. Hendley, at Jeypore, examined, for the purpose of the present inquiry, 100 children who were brought up (without any selection) for vaccination. Of these 78 were being dosed with opium, and 22 had not received opium. All the children of both groups were equally healthy.[1] Some of the medical witnesses expressed a formal disapproval of the habit, but added that they had not actually seen any evil result from it. Others again condemned the custom, and alleged that they had frequently seen serious malnutrition and fatal marasmus and atrophy follow the practice.

---

[1] A sect of Shia Mussulmans, called Bhoras, are said not to give opium to their children. Dr. Keegan, speaking at Indore, said of these :—'They happen to be the most unhealthy children in this part of the country, ... whether it is through not taking opium I do not know, but as a matter of fact the children of the Bhoras are very unhealthy.'

It is easy to believe that some minor infantile complaints, such as chronic constipation, might be unfavourably affected by the practice of giving opium to children, and benefited by its suspension, without attracting special notice from medical observers. But it is not easy to believe that serious marasmus and atrophy could, as alleged, frequently arise from a practice so common without having been long ago detected and generally recognised by medical practitioners and writers in India. Moreover, it is obvious that there must be some contributory factor or factors, in addition to the opium, to account for the production of such cases, otherwise more than half the children in some parts of India would be in a state of atrophy. The most convincing evidence on the occurrence of opium marasmus in infants was given by Dr. Huntly at Ajmere. He said: 'I can recall to my memory a dozen, or perhaps a score, of instances (of marasmus) in which, acting on my advice, the parents stopped the opium, and the child recovered health and plumpness.' Dr. Huntly was not able to indicate the contributory factors which accounted for these exceptional instances. It is well known that infantile atrophy may occur in otherwise healthy children simply as the result of insufficient breast milk in underfed or unhealthy mothers, or as the result of chronic functional derangements affecting the digestion and assimilation of food.[1] Children thus suffering would, in India, as a matter of course, be dosed with opium, and even cautious observers might be misled as to the true causal sequence. There is another group of cases, involving waste and emaciation, encountered in India, which might prove similarly deceptive. Children in India are liable, like adults, to the malarial cachexia, and infants in arms are sometimes found with the characteristic enlarged spleen. Mothers who suffer from malarial fever during pregnancy appear capable of transmitting the disease to their offspring congenitally or through their milk.[1] Such cases would be sure to have opium given them, and might easily be misinterpreted, especially in those instances, and they are not uncommon, where the malarial cachexia is unaccompanied with enlarged spleen.

---

[1] Prof. Henoch's description of infantile atrophy from these causes corresponds exactly with the description given of the so-called 'opium baby.' (*Lectures on Diseases of Children*, Syd. Soc. Ed., Vol. i., p. 72.)

In studying this most strange custom of giving opium to infants, it is necessary for the inquirer, if he is to reach valid conclusions, to divest himself of his European ideas concerning opium and infants, to examine the actual facts with an open mind, and, above all, to fully realise the complexity of the etiological problems involved. The following quotation from the evidence of Dr. Arnott, physician in charge of St. George's Hospital, Bombay, will, I think, find an echo in the experience of most medical men in India who have paid attention to this subject. 'On infants, who are otherwise well cared for, the use of opium has not the bad effect I was prepared to expect. I have seen many infants to whom opium was habitually given quite well-nourished and healthy; but others, ill-fed and ill-cared for, are emaciated; and, no doubt, among these last there is a large mortality. In such cases, it is not easy to separate the effects of opium from the other causes of infantile mortality in large towns.'

---

[1] Dr. Cleghorn, who was examined at Lahore, informed me privately that he had encountered enlarged malarial spleen in *new-born* infants and verified the fact at the autopsy.

(5.) USE OF OPIUM ON OCCASIONS OF CEREMONY.

In the protected States of Rajputana, Central India, and Gujarat opium is largely employed on various ceremonial occasions. It is so used during religious festivals, on State occasions, at the celebration of marriages, at births and funerals, as a token of welcome to friends, and as a seal of reconciliation between adversaries. A preparation called 'amal-pani' or 'kasumbha,'[1] is commonly used on these occasions. This is a strained solution of opium in water, and it is drunk in company, as a sort of social solvent, like wine. Opium in the solid form is also distributed, as largesse, by chiefs and hosts to relations, guests, retainers, and the poor. Some of the accounts of these customs laid before the Commission are very curious.

Sir Lepel Griffin thus describes the use of opium as a court observance in Rajputana:—'A Native Rajah with all his court sitting around him, will call for his attendant, who will pour some of it (opium water or amal-pani) into his hand, and he will drink it off, and every one of the men round him will drink it in the same way.'

A high Native official at Jeypore gives the following account of the ceremonial uses of opium among the people of the Jeypore state:—'On occasion of the annual celebration of the religious festivals of Akshay Tij, Holi, and Dusserah opium-eating is looked upon as highly auspicious and conducive to prosperity and happiness,

---

[1] According to Major Ferris 'kasumbha' is thus made in Kathiawar:—'Cut the opium into small pieces, add a little water, mix to a thick consistency, put the mass into a thick woollen cloth, pour cold water on gradually and strain through. Drink the decoction without any addition of sugar, or anything to destroy the bitter taste.' The proportion is usually one part of opium to 20 parts of water.

Opium is accordingly distributed among relations, as well as among friends and dependents, whether Hindus or Mahomedans, and the drug is partaken by all concerned as something sacred. Marriage contracts, and the celebration of marriage among Rajputs, are considered neither auspicious nor valid unless opium is eaten on such occasions. Opium is also used on occasions of funeral ceremonies. Moreover, when two inveterate enemies become reconciled and propose to pass the rest of their lives peacefully, they generally partake of opium at each other's hands; and the practice is recognised as making the tie of friendship inviolable. If either of the two parties decline to take opium, it is understood that he is not disposed to abide by his promises. It is generally the practice among natives of India to offer some refreshments to a friend or acquaintance who comes to pay a visit. Pan-supari (betel and betel nuts), tobacco, and spices, are often presented, but a Rajput would offer opium as an unmistakable token of friendship and attachment.'

An officer of the Dholpur State (Rajputana) relates 'That opium has been for ages an established institution in the country. It has come to be looked upon as the chief factor in some social customs and usages throughout Rajputana. For instance, it is customary among the Rajputs, at the betrothal ceremony, that the bridegroom should eat or drink opium offered by the bride's party. The whole company afterwards drink the drug by turn, out of the palm of the host. The extent to which opium has got itself wound up with the daily avocations of the people, as a tradition, will be realised from the fact that among the Thakurs and other high castes it is invariably seen that before beginning a letter, a prayer is expressed on top of it, asking the addressee to take, on the writer's account, double the quantity of his daily allowance' of amal-pani.

Here is a curious picture from Malwa, drawn by the Dewan (administrator) of the Rutlam State :—' I should like to add that there is attached to the Palace, at Rutlam, what is called an Abdarkhana, where respectable persons coming to see His Highness or the Dewan are treated with a drink of a solution made of opium (kasumbha). The Jagirdars, as also the servants of His Highness, and citizens who frequent the Darbar office, partake of the drink. If respectable Jagirdars and Thakores are not offered the kasumbha drink, they would feel that they are not treated properly. On a birthday, the Dasora holiday, and at the time of certain darbars, the Thakores, Jagirdars, officers, and others are treated with kasumbha. The darbar is dissolved after all the persons have resumed their seats after having taken the kasumbha. No pansupari, flowers, garlands, etc., are given in such darbars, the kasumbha taking the place of all these things. The Abdarkhana institution has been in existence from time immemorial. During the minority of his late Highness the Political Superintendent of the State had to maintain it, and it has been maintained up to this time, though nowadays it is used principally by persons of the middle class. Formerly it cost much, now the cost is much reduced. The importance of the kasumbha drink is so great that in friendly letters and invitations the Thakores, Rajas, Dewans, and others generally endorse in their own autograph as follows :—" After reading this letter, do you take kasumbha drink as a treat from me in honour of yourself." This request is considered complimentary, and is made by one not inferior in rank to the other. When a friendly letter with such a request is received, the request is in certain cases literally carried out by "at once having a kasumbha party in honour of the person who made the request."'

Among the occasions on which it is obligatory to take opium, the paymaster of the army of the Native state of Jaisalmir mentions the following singular instances:—'on the visit of a son-in-law to his father-in-law's house,' on 'the first removal of hair of a male child among Rajputs and Charans,' 'on the parting (or shaving in the middle) of the beard of Rajputs and Charans.'

In the Native states of Gujarat and Kathiawar similar customs prevail. Major Ferris gives the following account of kasumbha drinking among the Natives of the Kathiawar States:—'Among the Kathis kasumbha is consumed at all funerals, marriages, betrothals, and such like ceremonies. As a fact it is never refused, but there is no religious obligation to take it. Nevertheless, if a Kathi has the habit and refuses kasumbha on such an occasion it would cause offence. In cases of reconciliation after a quarrel among Kathis, the drinking of kasumbha, even by those not having the habit, is *de rigueur*. To refuse would be to raise a suspicion that the reconciliation was not sincere. Each party must take some, however little, or the reconciliation is incomplete. It is a necessity almost amounting to a religion for a guest of a Kathi to be given and to accept kasumbha. A failure on either hand is a grave breach of hospitality and respect. Promises and verbal contracts and agreements are sealed among Kathis by the parties drinking kasumbha together. This makes the fulfilment as binding as an oath. When families agree to divide the ancestral property by mutual agreement, *without* having recourse to documents and the law, the parties drink kasumbha to clinch the undertaking.'

A Native Inspector of Customs at Ahmedabad gives some picturesque details of the ceremonial use of opium in that district. He says:—'The Girasias and Kathis who live in the southern part of this district have always been using and been addicted to the habit of eating opium. . . . Kasumbha is prepared twice a day—that is, in the morning and evening, when poor wasavas (low class labourers), who are habitual opium-eaters, are supplied with opium according to their requirements. This is a mark of generosity. . . . It is a custom among these people that when guests come to them from a distance on any unusual occasion, or on ordinary business, the village barber, on behalf of the guests, invites the resident householders of the village to drink kasumbha. All those that assemble in response to the invitations are supplied with kasumbha by the guests at their own expense, and pieces of opium have also to be given according to the requirements of the persons invited. If one omits to do this, he is not considered respectable. Another class of people residing in this district are the Patidars and Kambis, who have always observed the following usages. On a wedding occasion one may use opium at his pleasure, but when a respectable old man dies, the use of opium in honour of his memory is indispensable. During the first eleven days after the death of the deceased, when the people of the surrounding villages, with whom such formalities are usually interchanged, come in crowds to offer condolence, kasumbha has to be supplied to them and their servants, and opium is also distributed among them. Afterwards, on the last, or thirtieth day, all persons with whom such formalities are usually interchanged, and all relations coming from a distance, assemble. This gathering is called Saraoni, and if expenditure on a large scale is contemplated, it is called Gam Saraoni. The greater the quantity of opium one dispenses on this occasion, the more credit he gets.'

It appears from the evidence of several witnesses that in Kathiawar, and throughout Gujarat, the ceremonial use of opium is on the wane, and tending to die out. This is attributed partly to the spread of Western ideas and the substitution of alcoholic beverages for opium, and partly to economic necessity. In recent years the price of opium in these districts has risen a good deal, owing to increased taxation upon it. In former times, when opium was almost untaxed, the quantities consumed on these ceremonial occasions was enormous. A Native gentleman from the neighbourhood of Ahmedabad informed the Commission that on the occasion of the death of his grandfather, in 1851, nearly three maunds, or 240 lbs., of opium were consumed in treating the guests, whereas on the occasion of the death of his father, thirty years later, in 1881, not more than 10 lbs. of opium were used by the guests.

(6.) OPIUM-SMOKING IN INDIA.

The use of opium in the way of smoking is a subordinate habit in India; and, as compared with the ancient practice of opium-eating, is relatively modern. Opium-smoking is practised in two ways—namely, as *madak-smoking* and as *chandu-smoking*. The preparation of opium used in these two modes is quite different, and the manner of smoking is also different.

Madak-smoking.—The substance called Madak (or Madat or Muddat) is prepared by dissolving crude opium in water, boiling the solution, and straining through cloth. The strained product in boiled down to a syrup, and then mixed with charred leaves, of acacia, betel, or guava, so as to form a soft mass. The mass thus obtained is finally divided into little balls about the size of small marbles.[1] Samples of madak balls obtained by me at Calcutta, have a light porous texture, and a carbonised appearance. The balls weigh a little under seven grains each. The quantity of opium contained in madak probably varies in different markets, but from the mode of manufacture it must be always an attenuated preparation as compared with chandu. Judging by the directions for the manufacture of madak given in Vol. IV., p. 521, and Vol. V., p. 87, of the Proceedings of the Commission, the proportion of opium contained in it would seem to vary from about one-third to about one-fourth. Mr. Gregory, the superintendent of the factory laboratory at Ghazipur, analysed two samples of madak purchased by him in the bazaar at Calcutta. They yielded respectively 0·18 per cent. and 0·21 per cent. of morphia. This proportion of morphia indicates that the madak sold in the Calcutta shops only contains about 4 per cent. of crude opium.

Madak is usually smoked in the ordinary hubble-bubble pipe. One of the little balls is placed in the bowl of the pipe and covered with a piece of glowing charcoal; it is then smoked much in the same way as tobacco.

Chandu-smoking.—Chandu (or Chundoo or Chundool) is prepared by boiling down a strained solution of opium in water in large copper caldrons to a thick consistency. As the concentration proceeds crusts form on the surface of the simmering mass; these are removed in succession as they form. These crusts are again dissolved in water, and the solution is again concentrated by boiling, until, finally, a thick extract is obtained of the consistency and appearance of thick tar. This is the 'smokeable extract' used in India by chandu-smokers. It is smoked in the freshly made or raw state, without any further preparation; and must be regarded as a coarse form of chandu.[1] The chandu used in China by the better classes is a much more elaborately prepared article, and is made to undergo, before it is considered fit for consumption, a gradual process of ripening, or maturation, lasting 10 or 12 months, whereby a delicate perfume is imparted to it, which is much prized by connoisseurs in chandu-smoking.[2]

---

[1] In Bombay madak is made up with the charred husks of a grain called moong. A substance called 'green gram' is employed in Southern India for the same purpose.

Chandu contains a large percentage of morphia. Mr. Gregory analysed a sample of chandu made with pure opium at the Ghazipur laboratory. He found it to contain 10·17 per cent. of morphia. Two samples of chandu purchased by him in the Calcutta bazaar yielded, respectively, 9·19 per cent. and 9·07 per cent. of morphia. It thus appears that Indian chandu is about twice as rich in morphia as the crude opium from which it is prepared.[1]

---

[1] It should be mentioned that the common chandu smoked in India, and by the poorer classes in China, has its quality lowered by the use, in the manufacture, of the dejections or 'dross' scraped from chandu pipes after they have been smoked. This 'dross,' which is rich in morphia, is carefully collected, and is largely employed to mix with the pure opium in the manufacture of the commoner sorts of chandu.

[2] A detailed account is given by M. Lalande, in the *Archives de Médecine Navale*, for 1890, of the method of making chandu from Bengal opium at the French Government Factory at Saigon. The process is carried out entirely by Chinese workmen, and is said to be an exact counterpart of the process followed in China for the production of high-class chandu. In the same journal for 1892 is a paper by Dr. Calmette describing the slow spontaneous fermentation which constitutes the ripening of the chandu. The fermentive agent, according to Calmette, is the Aspergillus Niger, or black mould, which grows everywhere so abundantly in saccharine media. The chemical results of the fermentation are to destroy the glucose of the opium and to convert the tannin into gallic acid, and to produce, besides, certain aromatic fragrances which impart the desired 'bouquet' to the finished article.

Chandu is smoked in a specially constructed pipe, and in a peculiar manner. The pipe-stem is composed of a tube of bamboo, about 20 inches long and more than an inch thick. One end is closed, and the other end is fashioned into a thick mouth-piece with a large orifice. About 7 inches from the closed extremity is a round hole, mounted in brasswork, for the reception of the neck of the bowl. The bowl of a chandu pipe is usually made of terra-cotta, and is entirely unlike the bowl of a tobacco pipe. The subjoined diagram (p. 314) will assist the reader to understand the description. The bowl (*a*) consists of a hollow disc, or chamber, about 2½ inches wide and about 1¼ deep. The upper surface is flatly convex, and at its centre (*b*) is a minute shallow cup, lined with metal, and perforated at the bottom with a small orifice. This leads to a short canal running through the terra-cotta, and is only wide enough to admit a medium-sized pin. The lower side of the disc is continued into a short neck (*c*) which fits into the opening in the pipe-stem.[2]

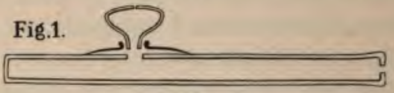
The chandu-smoker proceeds in the following fashion:—Armed with a pointed probe or style he dips the point into his supply of chandu and takes up a suitable quantity, which forms a little drop at the point of the style. This he now carefully heats over the flame of a lamp until it dries up into a soft pilule. He next transfers the little pilule to the shallow cup on the upper surface of the bowl. Then, assuming a reclining position, he cautiously applies the pilule to the flame of the lamp, and at the right moment, when the chandu begins to bubble and to emit smoke, he takes a full inspiration

---

[1] According to the analysis of Lalande (*l.c.*, p. 69) the chandu made at Saigon, while retaining its full complement of morphia, has only a very reduced proportion of anarcotine.

[2] The above description is drawn up from an examination of four chandu pipes, one bought at Calcutta, two confiscated pipes, kindly given to me by Mr. Westmacott, at Calcutta, and the fourth purchased in Rangoon. All four are essentially alike in construction, but vary in ornamentation. The bowls of the two confiscated pipes are made of brass, and the bowls of the other two are made of terra-cotta.

Fig.1.



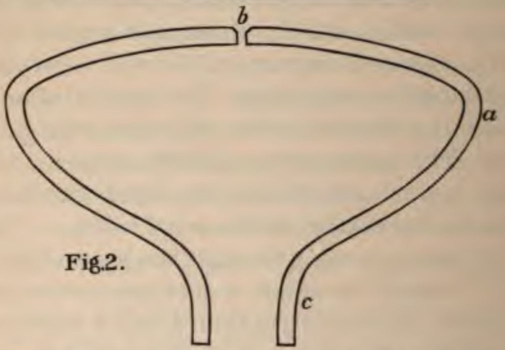


Fig.2.

FIG. 1. Vertical section through a chandu pipe, one-tenth the actual dimensions.
FIG. 2. Vertical section through the bowl of a chandu pipe, actual size. *a*. The bowl. *b*. The receptacle for the charge of chandu. *c*. The neck of the bowl.

and fills his lungs with smoke, and then slowly discharges it. One or two such inspirations exhausts the charge. A practised smoker will smoke 15 or 20 pipes at a sitting.

Opium-smoking in India is the habit of the comparatively few; it is almost confined to the towns, and is scarcely known among the country cultivators. Mr. Stoker, Commissioner of Excise for the North-Western Provinces and Oudh, who has had special opportunities of studying this subject, said that 'probably not so many as 1 in every 10,000 of the whole population ever smokes opium.' In the large towns and seaports the proportion of opium-smokers is considerably greater than this. In Bombay, with 821,000 inhabitants, Mr. Campbell, collector of Inland Revenue, estimated that before the closing of the licensed houses, in 1892, there were 700 or 800 men who smoked opium in the licensed premises—that is to say, about 1 in 1,100 of the entire population.

The practice of opium-smoking is generally looked down upon in India as a low and vicious habit. Several of the witnesses thought the practice—and especially that of madak-smoking—injurious to health. Others thought that the injurious effects were not due directly to the smoking, but were due to the associations and surroundings of the habit. These are certainly very bad. The practice of smoking seems to require that it shall be carried on in company, and the premises or 'dens' in which opium-smokers meet in India are of a squalid and insanitary character. The frequenters of these premises belong to the humbler grades of society. Many of them are, no doubt, decent working men, who call for their smoke much as English workmen call for their glass of beer; but these places are also the resort of idle and dissipated and vicious persons—the declassed and homeless waifs and strays who gravitate into large towns. It is easy to understand that such associations and surroundings would be deleterious to the health and corrupting to the morals of the young. Public opinion in India is against these 'dens,' and the consumption of opium in any form upon the premises of licensed shops is not now permitted.

The evidence with regard to the effect of opium-smoking on health was less complete and less conclusive than that with regard to opium-eating. Proof was given that smokers both of madak and chandu might continue the practice for 10, 20, or 30 years without detriment to their health. No organic disease of any kind was alleged to be producible by the habit. It was shown that opium-smoking was often resorted to for the relief of suffering, especially in cases of asthma, bronchitis, and pulmonary consumption, and that it was easy for unwary observers to mistake the effects of concurrent disease for the effects of opium-smoking. It cannot be said to have been adequately proved that moderate opium-smoking, taken by itself, and apart from its surroundings and from disease or semi-starvation, has a prejudicial effect on health.[1]

It is a matter of considerable scientific interest to know what the opium-smoker really takes into his system. As regards madak-smoking we have no positive information. Something, however, is known about chandu-smoking. Chandu is rich in the alkaloids of opium, and especially rich in morphia. These principles are, however, not volatilisable by heat; they are broken up and transformed by heat; and what the chandu-smoker receives into his lungs are the gaseous products evolved by the heated chandu, together with the carbonaceous particles which constitute the visible smoke.

Several Europeans have experimented in their own persons on chandu-smoking, and have recorded their experiences. Most of them report that they perceived no effects whatever, some suffered more or less from headache and giddiness, but none of the accounts I have seen report a distinctly hypnotic effect. Europeans are very sensitive to the hypnotic action of morphia, and their experience, even making allowance for their imperfect mastery of the art of chandu-smoking, seems to show that the enjoyment of the chandu-smoker is not due to the absorption of unchanged morphia. That some traces of morphia are conveyed into the lungs of the chandu-smoker is, however, pretty certain.[1] These traces would be carried up mechanically, in the solid form, entangled in the carbonaceous particles of the smoke. But as this smoke is forthwith expelled again, there would probably be very little absorption of morphia by the pulmonary tissue.

---

[1] The most detailed and circumstantial information, laid before the Commission, on the health of opium-smokers in India, is to be found in a publication entitled :—*Lives of Bombay Opium-Smokers*, compiled by Mr. Rustomji Jehangir, Chief Inspector of the Bombay Opium Department. This little book contains short biographies of 222 opium-smokers, of whom 60 were madak-smokers, and 162 chandu-smokers. These biographies are printed in full in the *Proceedings of the Commission*, Vol. IV., Appendix XXII.

What the gases evolved by heated chandu consist of we do not accurately know: they are doubtless very complex. But it may be presumed that their effect on the Eastern smoker is kindred, though not identical, with the reviving and exhilarating effect of solid opium on the opium-eater. It may, moreover, be assumed that the reason why Europeans (with rare exceptions) do not experience this reviving effect from chandu-smoking, is that they lack the proper constitutional susceptibility thereto, just as they equally lack, as before pointed out, the proper susceptibility to the reviving effect of the opium pill and opium draught.

---

[1] According to the observations of Moissan, made in the laboratory, the ripened chandu used by the better classes in China yields its smoke at a comparatively low temperature, and he was able to detect the presence of morphia in the smoke, together with some volatile perfumes. The coarser chandu smoked by the lower classes, which is made with opium adulterated with the 'dross' scraped from old chandu-pipes, requires a higher temperature for the development of smoke, and this smoke contains toxic compounds such as pyrrol, acetone, pyridic and hydropyridic bases (*Comptes Rendus de l'Académie des Sciences*, December 5, 1892). These toxic compounds appear to be somewhat similar with those found in tobacco smoke.

INDEX

ACHROMIC POINT, 69
Acid dyspepsia, 235
— of acid dyspepsia, 239
— of gastric juice, 40
Acids, effects of, on salivary digestion, 118
Alcoholic beverages, effects of, on digestion, 115, 132, 157
— — use of, 99
Anarcotine, 291
Antacids, in acid dyspepsia, 251
— with milk, 183
Artificially digested food, 192, 227

BEEF-TEA, 184
— — effects of, on digestion, 125, 140
— — peptonised, 205
Beer, *see* Malt liquors
Blanc-manges, peptonised, 204
Boracic solution, 17
Butyric acid in dyspepsia, 240

CANE-SUGAR, digestion of, 36
Casein, digestion of, 197
Chandu-smoking, 311
Chloroform as an antiseptic—note, 225
— water, as a solvent for digestive ferments, 18
Cocoa, effects on digestion, 120, 139
Coffee, use of, 101
— effects on digestion, 120, 138
Cooking, effects of, on food, 177
Cramp, gastric, 247

DIALYSIS, of food-accessories, 149
Diastase, action of, 19
— various kinds of, 219
Diastasimetry, 68
Diet, change of, 168
— diversity of, 164
— double aim of, 163
— mid-life, revision of, 171
— useless restrictions on, 165
Dietetic customs, 97
Dietetics, scientific basis of, 96, 162
Digestion, exterior, 4
— in general, 3
— interstitial, 6
— of cane-sugar, 36
— of fats, 59
— of milk, 196
— of proteids, 39
— of starch, 19
Digestive ferments, 9
Dyspepsia, acid, 235
— symptoms of, 237
— treatment of, 250

EFFERVESCENT waters, effects of, 119, 137
Egg-albumen, digestion of, 51
Eggs, beaten-up, 186
Enemata, peptonised, 218
Enzymes and Enzymosis, 15, 16
Euphoric agents, 263

FARINACEOUS flours, different kinds of, 188
Fats, digestion of, 59
Ferment, emulsive, 59
— inversive, 36
— milk-curdling, 56
— proteolytic, 39
Ferments, digestive, 9
— diastasic, 19
Flatulence, in acid dyspepsia, 244
Food, effects of cooking on, 177
— peptonised, 200
— store, 7
Food-accessories, effects of, on digestion, 112, 127, 143

GASTRIC-JUICE, acid of, 40
— — action of, on diastase, 43
Gruels, fortified, 187
— predigestion of, 229
— peptonised, 202
Gum lozenges, use of, 257

HEARTBURN, 244

INFUSION OF MALT, 224
— of meat, cold-made, 185
Inversive ferment, 36

JELLIES, peptonised, 204

KASUMBHA, 305
Kitchen, sick-room, 190
Kittens, experiments with, 209

LIQUID FOODS, 182
Liquor pancreaticus, 195
Lozenges, in acid dyspepsia, 251

MADAK-SMOKING, 310
Malt, diastasic value of, 79
— extracts of, 223
— infusion of, 224
— preparations of, 222, 226, 227
Malt liquors, effects of, on digestion, 119, 136
Man-value, calculating the, 109
Meat, use of, 98
— cold-made infusions of, 185
Metacasein, 198
Metacasein-reaction, 80
Milk, as a liquid food, 183
— pancreatic digestion of, 196
— peptonised, 200
Milk-curdling ferments, 56
Milk-gruel, peptonised, 203

NOMENCLATURE, suggestions on, 15

OPIUM, as a household remedy, 285
— as a prophylactic, 288
— composition of, 291
— given to infants, 298
— on occasions of ceremony, 304
Opium-habit in India, 261
Opium-pipe, 314
Opium-smoking, 310
Oysters, 178

PALATE, office of the, 166
Pancreas, enzymic value of, 89
Pancreatic digestion, effects of food-accessories on, 156
— extracts, preparation of, 16, 69
— — estimation of activity of, 66
— — action of, on egg-albumen, 51
— — — — on gelatine, 205
— — — — on milk, 196
— — — — on starch, 20, 27
Pepsin, 39, 51
— effect of varying quantities of, 131
Peptic digestion, effects of food-accessories on, 127
Peptogens, 54
Peptones, 48
Peptonised food, 194
— — preparation of, 200
— — nutritive value of, 206
— — clinical experience of, 213
Plants, digestion in, 7

Proteids, digestion of, 39
Proteolysis, digestive, 47
Pyrosis, 247

Rennet, 56
Rennin, 56
Retardation of digestion, 143, 144, 153

Saliva, diastasic value of, 79
Salivary digestion, 20, 27, 43
— — effects of food-accessories on, 112
Salivation, defective, 221
— in acid dyspepsia, 245, 255
Salt, use of, 156
Salts, effects of, on digestion, 146
Soda, with tea, 123
Soups, use of, 152
— peptonised, 204
Starch, digestion of, 19, 219
— effects of cooking on, 19, 179
Starch mucilage, standard, 69
Superacidulation, effects of, 147

Tannin, in tea, 121
— effects of, on digestion, 122, 140
Tea, use of, 101
— effects of, on digestion, 121, 139, 158, 159
Trypsimetry, 80
Trypsin, 39, 51

Urine, diastasic value of, 79

Vinegar, effects of, on digestion, 118

Whey, effects of, on digestion, 140
Wholemeal, 191
Wines, effects of, on digestion, 117, 134

PRINTED BY
SPOTTISWOODE AND CO., NEW-STREET SQUARE
LONDON

'A compendium of trustworthy information.'—THE TIMES.

CROWN 8VO. 6s.

THE SPAS AND MINERAL WATERS OF EUROPE.

WITH NOTES ON BALNEOTHERAPEUTIC MANAGEMENT IN VARIOUS DISEASES AND MORBID CONDITIONS.

By HERMANN WEBER, M.D., F.R.C.P.

Consulting Physician to the German Hospital and to the Royal National Hospit Consumption, Ventnor, &c.; and

FREDERICK PARKES WEBER, M.D., M.R.C.P.

Physician to the German Hospital.

'Contains in a brief space a large amount of most useful information in regard to the spas and mineral waters of Europe. . . . This information is the outcome of personal knowledge on the part of the authors.'—NATURE.

'There is a voluminous bibliography in the book, no lack of exact facts and statistics, and much sound advice about exercise, diet, massage, and the like.'—SPEAKER.

'A welcome addition to the English literature of the subject. It is extremely well arranged, and constitutes a most useful and reliable guide to the various spas of Europe.'—THE HOSPITAL.

DR. W. B. CHEADLE.

FOURTH EDITION, REVISED. CROWN 8VO. 5s.

ON THE PRINCIPLES AND EXACT CONDITIONS TO BE OBSERVED IN THE ARTIFICIAL FEEDING OF INFANTS;

THE PROPERTIES OF ARTIFICIAL FOODS; AND THE DISEASES WHICH ARISE FROM FAULTS OF DIET IN EARLY LIFE.

A Series of Lectures delivered in the Post-graduate Course at St. Mary's Hospital, and at the Hospital for Sick Children, Great Ormond Street, 1887.

By W. B. CHEADLE, M.D.

Physician to St. Mary's Hospital, and Lecturer on Medicine, &c.

'We can strongly recommend this little work. . . . It testifies to a clear perception of the difficulties of the subject, and of the best ways of overcoming them.'—HOSPITAL GAZETTE.

DR. A. S. DONKIN.

CROWN 8VO. 5s.

ON THE RELATION BETWEEN DIABETES AND FOOD, AND ITS APPLICATION TO THE TREATMENT OF THE DISEASE.

By ARTHUR SCOTT DONKIN, M.D.Edin., M.D.Durh.

Member of the Clinical Society of London; late Lecturer on Forensic Medicine and Examiner in Medicine in the University of Durham, &c. &c.

DR. P. M. BRAIDWOOD.

CROWN 8VO. 2s. 6d.

THE DOMESTIC MANAGEMENT OF CHILDREN.

By P. M. BRAIDWOOD, M.D.

Surgeon to the Wirral Hospital for Sick Children.

London: SMITH, ELDER, & CO., 15 Waterloo Place.

SMITH, ELDER, & CO.'S TEXT-BOOKS.

MILNES MARSHALL'S VERTEBRATE EMBRYOLOGY: A Text-Book for Students and Practitioners. With numerous Illustrations. 8vo. 21*s*.

MARSHALL'S and HURST'S JUNIOR COURSE of PRACTICAL ZOOLOGY. Fourth Edition. Revised by C. HERBERT HURST. With Illustrations. Crown 8vo. 10*s*. 6*d*.

ELLIS' DEMONSTRATIONS of ANATOMY. Edited and Revised by G. D. THANE, *Professor of Anatomy*, University College, London. Eleventh Edition. With Illustrations. Small 8vo. 12*s*. 6*d*.

CLELAND'S DIRECTORY for the DISSECTION of the HUMAN BODY. Third Edition. Thoroughly Revised by JOHN YULE MACKAY, M.D. Fcp. 8vo. 3*s*. 6*d*.

HOLMES' TREATISE on SURGERY: its Principles and Practice. Edited by T. PICKERING PICK, Surgeon to, and Lecturer on Surgery at, St. George's Hospital. Fifth Edition. With 428 Illustrations. Royal 8vo. 30*s*.

HEATH'S DICTIONARY of PRACTICAL SURGERY. Third Edition. 2 vols. Royal 8vo. 32*s*. cloth; or half-morocco, marbled edges, 42*s*.

KEETLEY'S INDEX of SURGERY. Fourth Edition. Crown 8vo. 10*s*. 6*d*.

CHEYNE'S ANTISEPTIC SURGERY: its Principles, Practice, History, and Results. With 145 Illustrations. 8vo. 21*s*.

CHEYNE'S MANUAL of the ANTISEPTIC TREATMENT of WOUNDS. With Woodcut Illustrations. Crown 8vo. 4*s*. 6*d*.

NOBLE SMITH'S SURGERY of DEFORMITIES: a Manual for Students and Practitioners. With 118 Illustrations. Crown 8vo. 10*s*. 6*d*.

BRISTOWE'S TREATISE on the THEORY and PRACTICE of MEDICINE. Seventh Edition. 8vo. 21*s*.

FINLAYSON'S CLINICAL MANUAL for the STUDY of MEDICAL CASES. Third and Cheaper Edition. With many new Illustrations. Crown 8vo. 8*s*. 6*d*.

TAYLOR'S INDEX of MEDICINE: a Manual for the Use of Senior Students and others. With Illustrations. Crown 8vo. 12*s*. 6*d*.

PAYNE'S MANUAL of GENERAL PATHOLOGY. With Coloured Plate and 150 Woodcuts. Crown 8vo. 12*s*. 6*d*.

GEE'S AUSCULTATION and PERCUSSION. With Illustrations. Fourth Edition. Fcp. 8vo. 6*s*.

PLAYFAIR'S TREATISE on the SCIENCE and PRACTICE of MIDWIFERY. Eighth Edition. With 198 Illustrations and 6 Plates. 2 vols. Demy 8vo. 28*s*.

BARNES' SYSTEM of OBSTETRIC MEDICINE and SURGERY. In 2 vols. 8vo. With numerous Illustrations. Vol. I. 18*s*. Vol. II. 20*s*.

JULER'S HANDBOOK of OPHTHALMIC SCIENCE and PRACTICE. Second Edition, Revised. With numerous Illustrations 8vo. 21*s*.

FARQUHARSON'S GUIDE to THERAPEUTICS. Fifth Edition. Crown 8vo. 7*s*. 6*d*.

WOOD'S THERAPEUTICS: its Principles and Practice. Ninth Edition, thoroughly Revised. 8vo. 18*s*.

Messrs. SMITH, ELDER, & CO. will be happy to forward a copy of their Catalogue post free on application.

London: SMITH, ELDER, & CO., 15 Waterloo Place.

U216 Roberts, Sir W. 903
R64 Collected contributions o
1897 digestion and diet.

NAME	DATE DUE

U216 Roberts, Sir W. 90
R64 Collected contributions
1897 digestion and diet.

NAME	DATE DU